SUMMARY

NOISE AND RFI MEASUREMENTS: BASIS FOR THE TESTS

The relatively poor Loran-C signals in the Los Angeles area indicated by a Teledyne Survey prompted an investigation and identification of the primary types of noise and RFI that a Loran-C receiver operating in the urban and suburban environment of Los Angeles would encounter. The literature provides excellent information which can be used to predict the natural atmospheric noise areas (1) but at that time very little (if any) information was available on the interference to be found in the urban environment. However, it was known that terrestrial Loran-C experiments in Tennessee were experiencing problems. Since the time corresponding to the SCI tests, a test program has been conducted in Tennessee for the U.S. Department of Transportation to determine the effects of high voltage TVA transmission lines (operating with and without supervisory carrier signals) on the performance of typical Loran-C receivers. The results of these tests have been published in a document (2) available to the public. The SCI Los Angeles test results correlate well with the quantitative measurements and conclusions of this late Tennessee work. The SCI data supplements and extends the Tennessee report by identifying other major types and sources of noise and interference which may be expected in the signal environment of urban and suburban Los Angeles. A detailed description of the SCI tests and results are presented in this report.

LOS ANGELES (SCI) MEASUREMENTS: SUMMARY

The measurements of man-made noise and RFI in the urban and suburban areas of Los Angeles provided considerable insight into the many types of noise sources and the spatial characteristics of some of these sources. The SCI measurements identified the following types of high-level man-made noise and interference as factors which may limit the performance of Loran-C receivers in urban and suburban areas:

(1) Impulsive Noise
(2) Power Line Carrier Communications
(3) Localized Continuous Wave Signals

(4) Low Level Signals

(5) Ignition Noise

(6) Conventional Power Line Noise.

Implusive Noise

Severe impulsive noise was found to exist in a number of locations. The spectral shapes of implusive noise were observed to vary from relatively flat (in which case the RF filter of measurement equipment established the observed spectral shape) to non-frequency-flat spectral shapes implying that frequency-selective properties are associated with the noise signal. The primary source of the radio noise was found to be impulses emanating from nearby electric utility lines. In some cases, the noise could be associated with a particular distribution line. In almost all cases, primary time intervals between impulses of 16.6 and 8.3 ms were observed in the data. These intervals can be associated with 60 and 12 Hz triggering rates. In some cases, the data can be related to three-phase sources with 16.6 and 8.3 ms intervals having slightly different phase relationships. This noise appears to be due to utility customers who employ high power solid state or gaseous switching devices for industrial process control (SCR). The transmission mechanisms between the actual source and the Loran-C antenna (which may be located several blocks or even miles away from the source) is not well understood. The near-field coupling mechanism between the Loran-C antenna and the power lines cause the noise levels to vary by large values over very short distances (tens of feet). In some cases, the amplitudes of the impulsive noise were observed to change as much as 50 dB over a distance as short as 100 feet. In these instances, the received Loran-C signal-to-noise ratios would change from a relatively high positive value to a high negative value (approximately -20 dB and greater) which would significantly degrade the performance of most Loran-C receivers.

Power Line Carrier (PLC) Communications

The second most serious type of interference observed was associated with radiation from electric utility transmission lines. Electric utilities employ low frequency carriers for voice communication, analog telemetry, and digital data transmission. These signals are used for the supervision, control, and protection of power generation and transmission facilities. CW signals associated with this type of source were recorded by SCI and have also been observed at numerous locations and frequencies during and after the SCI measurements. It is believed that PLC's with frequency spacings as dense as every 1 kHz in the Loran-C and adjacent frequency spectrum (60-140 kHz) exist in Southern California. SCI documented relatively high level CW signals at approximately 80, 90, 100, and 108 kHz and relatively low level signals at about 103, 120, 130, 140, and 150 kHz. The impact of these CW signals on the performance of a Loran-C receiver is dependent upon the complex combination of a number of important factors:

(1) PLC transmission frequency
(2) PLC signal strength
(3) Available Loran-C signal strength
(4) Synchronous/Asynchronous properties of PLC
(5) Loran-C receiver design.

The received PLC signal strength is primarily a function of the proximity of the Loran-C antenna to the power lines, the PLC frequency relative to the receiver bandpass, and the power of the PLC transmitter. Electric utility companies are known to use PLC transmitter powers ranging between 1 and 100 watts. The SCI and Gould measurements noted CW signal levels sufficient to degrade the Loran-C receiver performance of two different commercial receivers at ranges from power lines form approximately 100 feet to several thousand feet.

Other Types of Interference

The SCI measurements also identified other types of noise and interference which affect the operation of Loran-C receivers to a lesser degree. Types of interference included in this category are localized CW signals, ignition noise, conventional power line noise and far-field CW signals. In general, these types are considered less serious because of one or more of the following factors:

(1) Infrequent occurrence

(2) Very localized nature

(3) Frequency can be notched out.

The SCI measurements observed locations where very localized CW signals at or near 100 kHz were present. Signal properties varied with location. At several street intersections there was observed a very localized CW signal within the Loran-C spectrum. This appeared to be associated with traffic control sensors. In at least two other cases, CW signals were observed in the Loran-C spectrum with frequency spacings of approximately 16 kHz. Here the constant separation and simultaneous rise and fall of all CW signals suggested that a single nearby source was involved. (TV horizontal sync pulses at 15.75 kHz have been observed to cause problems with marine Loran-C receivers on ships and boats in the past.) At a few locations, CW signals at or close to 100 kHz were recorded which were associated with unshielded overhead telephone lines. The only far-field signal observed by Gould or SCI over a wide area of the Los Angeles vicinity was from a Navy transmitter located in Northern California operating at approximately 120 kHz. The notches of the Loran-C receiver can be set to attenuate this particular signal.

1. INTRODUCTION

Radio noise and RFI at and near frequencies employed by Loran-C radio navigation systems were investigated in portions of Los Angeles, California. Emphasis was placed on the definition of the detailed time and frequency domain structure of noise and RFI which might degrade the reception of Loran-C signals in urban, suburban, and industrial areas of Los Angeles. Furthermore, the measurements were directed toward obtaining an understanding of the noise and RFI environment which would be encountered by vehicularly installed Loran-C navigation systems.

The measurements were made at and around the 100 kHz band of frequencies employed by Loran-C, and they were made from a mobile van. An attempt was made to duplicate the vehicular antenna installations employed by many Loran-C receiving systems and to achieve a signal detection sensitivity comparable to Loran-C receivers. The noise and RFI instrumentation was somewhat different than the instrumentation used for conventional measurements, and it is described in Section 2. While the instrumentation was capable of collecting data to provide comprehensive statistical descriptors of noise, this was not done. The measurements were primarily of a diagnostic nature where data were rapidly collected at a very large number of sites and during mobile operation. These data were employed to achieve an understanding of the detailed properties of noise and RFI at each site and while moving along streets and highways. The output format of the data, Polaroid photographs of calibrated 3-axis views of noise, RFI and Loran-C signals, was chosen to provide a simplified and rapid means of describing noise and RFI at each site and to permit the comparison of conditions from site to site. In addition, an attempt was made to gather data which would permit the comparison of actual noise and RFI conditions with the performance of Loran-C receivers installed in mobile vehicles.

The Phase I measurements described in this report were made during the period of December 18 through December 22, 1978, while the Phase II measurements were made during the period of January 22 through January 27, 1979.

2. INSTRUMENTATION

The instrumentation used to acquire data presented in this report is described in Figure 2-1. A standard 108 inch long whip antenna was employed to sense signals and noise. A low noise preamplifier was used to achieve a signal detection capability roughly equivalent to the RF sensitivity of a Loran-C receiver. An RF bandpass filter was employed in the preamplifier to prevent intermodulation product generation in the amplifier and subsequent stages from nearby radio stations and nearby radio broadband noise sources during the Phase I measurements. However, most of the data taken during Phase II were taken without the RF filter. A Hewlett-Packard Series 140 Spectrum Analyzer was employed as a scanning receiver to drive an EMTEL Model 7200B 3-Axis Display. The 3-axis display provided a moving real-time visual representation of signals and noise received by the scanning receiver.

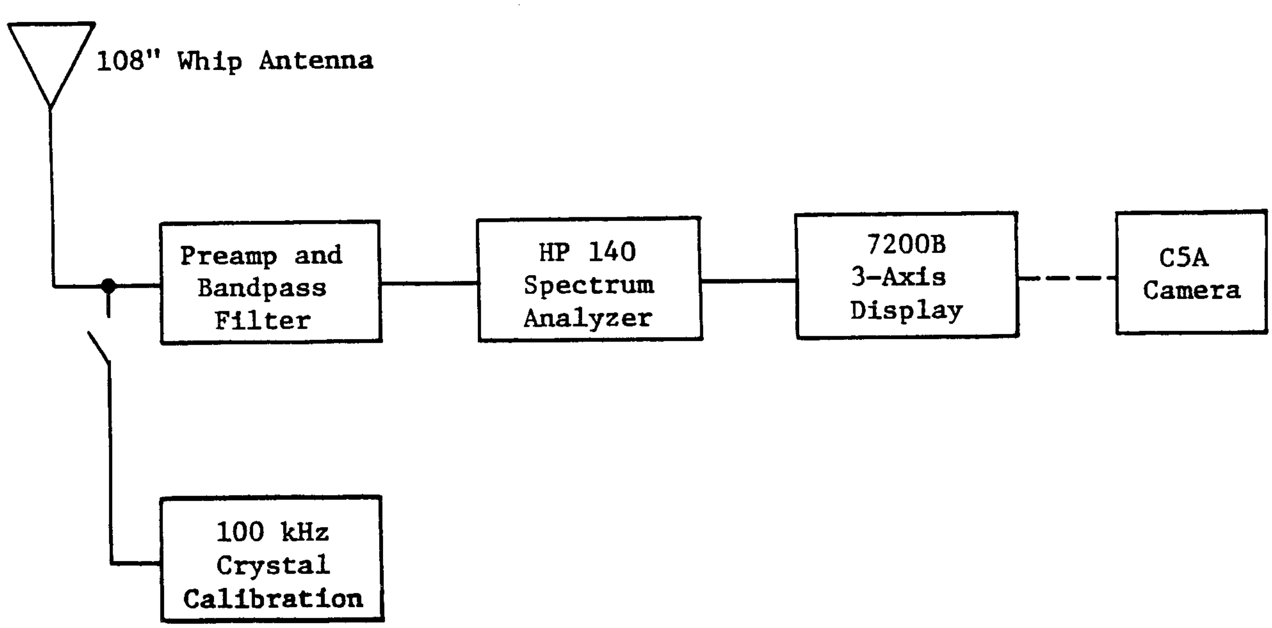


FIGURE 2-1. BLOCK DIAGRAM OF NOISE AND RFI MEASUREMENT SYSTEM

The instrumentation was installed in an Econoline van for mobility and convenience in noise and signal measurements. The van was driven along streets representative of conditions encountered by urban and suburban area vehicles and to some locations previously identified as problem areas for Loran-C reception. Both mobile and fixed location measurements were made as necessary to define a particular noise or signal situation.

To acquire data the spectrum analyzer was adjusted to scan across a block of frequencies centered at 100 kHz. As the spectrum analyzer scanned through a block of frequencies, its output was divided by the 3-axis display into 512 equally spaced data points. The received signal or noise amplitude at each data point was represented by an 8-bit digital word which provided an amplitude resolution at 256 levels for each data point. When a scan was completed, the 512 amplitude words were stored in memory and then presented as line 1 on the display CRT. When the second scan was completed, its data were stored in memory, line 1 on the CRT moved to line 2, and the new scan was shown on line 1. Subsequent scans moved the earlier lines step by step along the time axis until the entire memory was filled and a total of 60 scan lines were presented in the 3-axis view. When the memory was full, each new scan caused the oldest scan to be discarded. The resulting animated moving view of signals and noise provided a unique and easy-to-interpret visual picture of noise and signals in the blocks of frequencies under observation.

The 3-axis display system has a number of controls to assist the operator in interpreting the signals. Among these controls are a stop-action control to freeze any desired view for detailed observation, geometry controls to vary the viewing aspect, display mode controls to select any segment of the total view for detailed examination, and a threshold control to vary the background noise level.

The 3-axis views presented in this report were obtained by photographing the display in its stop-action mode. In interpreting the data, consideration must be given to situations where repetitive impulsive signals are observed by the repetitive scanning process. The relative repetition rates of impulsive signals and the scan rate of the receiver produce distinctive bands that slant across the CRT.

System calibration factors necessary to accurately scale the 3-axis views are as follows:

Preamplifier Gain	18 dB
Preamplifier Gain Without Filter (Phase II only)	15 dB
30 kHz IF Bandwidth Factor	0 dB
10 kHz IF Bandwidth Factor .... (Apply to Loran-C and noise but not CW signals)	8 dB
3 kHz IF Bandwidth Factor .... (Apply to Loran-C and noise but not to CW signals)	12 dB
1 kHz IF Bandwidth Factor .... (Apply to Loran-C and noise but not to CW signals)	20 dB

The RF bandwidth of the preamplifier filter is shown in Figure 2-2. Appropriate gain versus frequency calibration factors for views which used the filter can be scaled from the filter bandwidth curve.

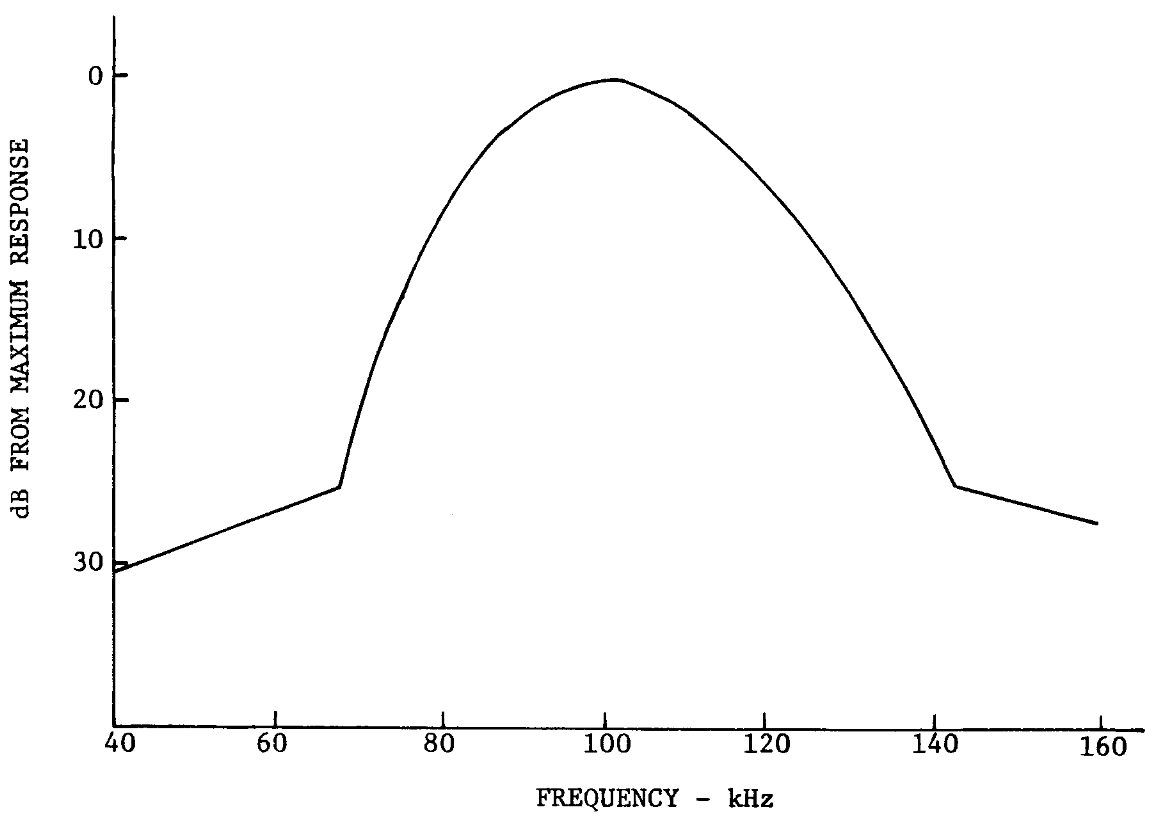


FIGURE 2-2. PREAMPLIFIER BANDPASS FILTER RESPONSE

To accurately scale the absolute amplitude of Loran-C, noise, and CW signals at the antenna output (or preamplifier input), the system calibration factors must be applied to the amplitude scale on each set of 3-axis views in this report. These system calibration factors can be applied as described in the following steps.

1. An 18 dB factor has been applied to all Phase I 3-axis display amplitude scales to account for preamplifier gain; for Phase II scales a 18 dB or 15 dB factor has been applied.

2. Use the appropriate IF bandwidth factor:

   a. If the IF bandwidth is 10 kHz, add 8 dB to each Loran-C or noise amplitude measurement.

   b. If the IF bandwidth is 3 kHz, add 12 dB to each Loran-C or noise amplitude measurement.

   c. If the IF bandwidth is 1 kHz, add 20 dB to each Loran-c or noise amplitude measurement.

3. If the preamplifier bandpass filter was used and if the measured noise, Loran-C, or CW signal amplitude is more than ± 10 kHz from 100 kHz, obtain an RF bandpass calibration factor from the filter characteristic curve and add this dB value to the measured amplitude.

The noise, Loran-C, or CW received signal levels obtained after taking the system calibration factors into account will describe the signal level available to a Loran-C receiver when connected to a mobile 108 inch whip antenna. These values can also be used to convert measured received power into field strength values by employing appropriate antenna conversion factors. Typical antenna conversion factors are available from a number of sources.

Each 3-axis view is identified by a two-line code where the top line gives (1) the date of measurement, (2) the local time of day of the measurement, and (3) the site location or site identification number. The second line gives a number of system-oriented parameters, where the various parameters are (1) the model of scanning receiver (always an HP 140 Spectrum Analyzer for the Phase I and II measurements), (2) the antenna (always a 108 inch whip), (3) the center frequency (F), (4) the frequency scan width (W), (5) the IF bandwidth, and (6) the scan time (ST). The last item for the Phase I measurements consists of two numbers necessary to establish an amplitude calibration for each view where the first number gives the RF attenuator setting for the HP 140, and the second number is the IF attenuator setting. For the Phase II measurements the last item consists of three numbers necessary to establish an amplitude calibration for each view where the first number gives the IF calibration factor for the HP 140, the second number gives the HP 140 RF attenuator setting, and the third number gives the RF preamplifier gain. When the letters NF follow the three amplitude calibration numbers, a broadband RF filter was employed and amplitude versus frequency calibration factors are not required. When the letters BPF appear, this indicates an RF bandpass filter was used and amplitude versus frequency factors from Figure 2-2 must be applied to the 3-axis view.

3. PRESENTATION OF SIGNIFICANT DATA

3.1 GENERAL APPROACH

Prior measurements of Loran-C receiver performance had been made in portions of Los Angeles by the technical staff of Gould Inc. These measurements identified certain streets, street intersections, and general areas where Loran-C receiver performance was marginal and at times inadequate. These locations were received from Gould personnel, and they served as the basis for selecting the locations of noise and RFI measurements described in this section.

In general, the measurement van was driven to an area identified by Gould Inc., and noise was examined as the van was slowly driven along a selected street. When unusual conditions were observed, a repeat run would be made, or the measurement van would be parked at a specific location for detailed fixed location measurements. Additional streets and areas were surveyed while proceeding to, between, and from sites. These additional measurements augmented data collected at the prescribed sites.

Very little technical data on the details of the noise and RFI were available prior to the measurements. Thus, some time was used to become familiar with the various kinds of noise and RFI encountered in Los Angeles. As the various sites were visited and the general properties of the noise and RFI were developed, consideration was given to important factors such as defining noise and RFI characteristics, spatial coverage, relationships to nearby physical objects, possible sources, and other items needed to describe the noise and RFI environment.

As the data were collected it became obvious that the noise and RFI could be placed into convenient categories, and these categories could be rated in terms of overall importance. Subsequent subsections of this report are organized in accordance with the various categories selected to describe conditions in Los Angeles. These subsections contain examples of the 3-axis display views to illustrate the results obtained. The text describes each set of 3-axis views and discusses the important features of each view.

3.2 BEST LORAN-C SIGNAL RECEPTION

Reference 3-Axis Views: 12/21/78, 1009 (Figure 3-1)
12/22/78, 1107 (Figure 3-2)

The 3-axis views taken on 12/21/78 at 1009 show the amplitude (upper view) and timing (lower view) of Loran-C signals received in Los Angeles during very low ambient noise and RFI states. The lower photograph shows four clustered slanting lines downward through the view, and a set of single slanting lines at a different angle. Each line of a group of four represents the eight sequential pulses of a particular station in the U.S. West Coast Chain where the first signal from the left is the Master (Fallon, Nevada); the second signal is W (George, Washington); the third signal is X (Middletown, California); and the fourth signal is Y (Searchlight, Nevada). The set of single slanting lines is Y (George, Washington) of the West Coast Canadian Chain, which has a slightly different time spacing between successive signals from a given station when compared to the U.S. West Coast Chain. The distinct visual signature in the 3-axis views caused by the slight timing difference allowed signals from either chain to be immediately identified.

The upper view shows the same data of the lower view with the display elevation control changed from full elevation to 0° elevation, amplitude compression removed, and the azimuth control adjusted to line up all 60 scans of data for the U.S. West Coast Chain. This view shows the amplitudes of each signal and provides a good estimate of the S/N for each signal. Signal amplitudes should be measured at the 100 kHz frequency region near the center of the x-axis since some signal reduction will occur at the left and right edges of the view due to less signal energy at 95 and 105 kHz.

A second related and similar view of Loran-C signals is shown in the views taken on 12/22/78 at 1107, where the receiver scan width is increased from 10 kHz to 50 kHz. The Loran-C signals are compressed toward the center of the frequency axis.

In these views the fourth pulse group of the U.S. West Coast Chain (Searchlight, Nevada) is the strongest at about -50 dBm when referenced to the scanning receiver input; the next strongest is the third pulse group (Middletown, California); the next is the first pulse group or the Master station (Fallon, Nevada); and the weakest is the second pulse group (George, Washington). A CW signal is shown at about 117 kHz at a level about 4 dB below the Master station signal and 18 dB below the strongest signal. Peak signal to average noise estimates of each signal are as follows:

Station	S/N
Y	+20 dB
X	+15 dB
M	+ 7 dB
W	+ 4 dB
CW	+ 3 dB

The two sets of views are typical of the best Loran-C signal reception found in Los Angeles, and they represent baseline cases for establishing optimum signal levels for performance estimates.

12/21/78, 1009, Grand & 54th St. (parked)
HP 140, Whip, F 100 kHz, W 10 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -20 dbm

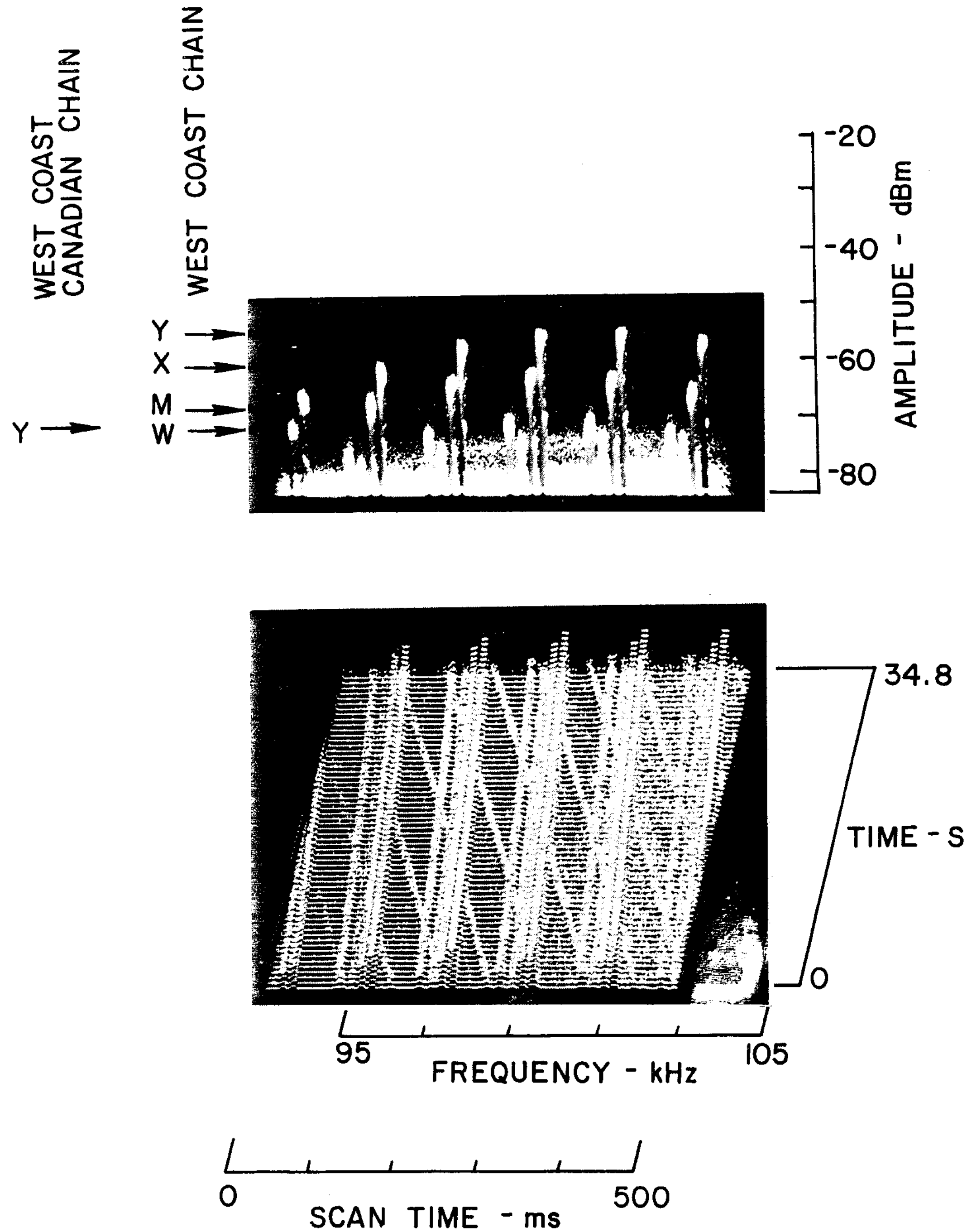
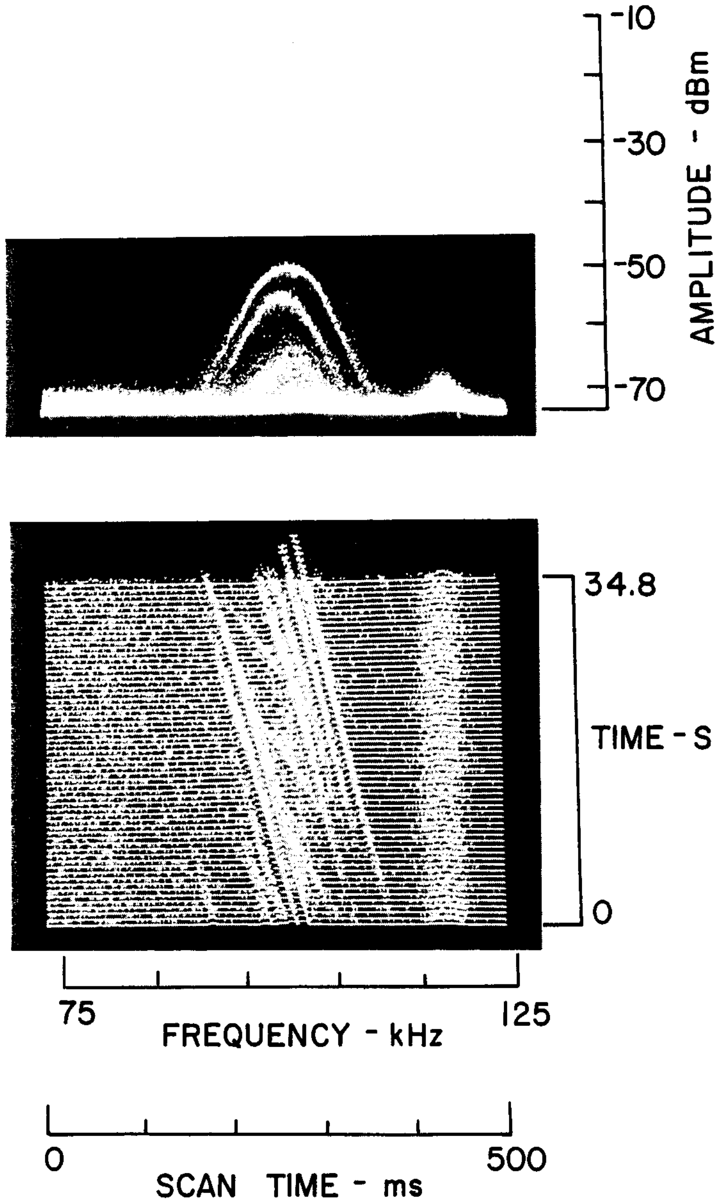


FIGURE 3-1. 12/21/78, 1009



12/22/78, 1107, 51st St. & Compton
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -10 dbm

FIGURE 3-2. 12/22/78, 1107

3.3 SEVERE IMPULSIVE NOISE

Reference 3-Axis Views:	12/19/78, 1358 (Figure 3-3)
	12/19/78, 1311 (Figure 3-4)
	12/18/78, 1303 (Figure 3-5)
	12/18/78, 1510 (Figure 3-6)
	12/22/78, 1150 (Figure 3-7)
	12/22/78, 1142 (Figure 3-8)
	12/22/78, 1143 (Figure 3-9)

The above-listed views portray cases where severe impulsive noise was observed. The views have been selected to define the properties of the impulsive noise as well as to show examples of Loran-C signals immersed in the noise.

The 12/19/78, 1358 view (lower photograph) shows Loran signals which were free of noise in the upper portion of the view. As the measurement van moved along Compton St. toward 53rd St. (and approached an overhead electric distribution line along 53rd St. which connected to a line along Compton starting at 53rd St.), severe impulse was encountered. The noise abruptly increased in level at 53rd St. and reached a peak amplitude of 40 dBm (about 10 dB above the strongest Loran-C signal). The noise decreased in level about 10 dB as the measurement van moved along Compton, and the noise amplitude remained about equal to the strongest Loran-C signal along Compton for the remainder of the block.

The noise impulses are uniformly spaced at 8.3 ms intervals, which suggests that the noise source was a high power switching device operating on both the positive and negative portions of a 1Ø power line. The spectral shape of the noise was similar to the RF filter shape of the preamplifier filter, suggesting that the noise was essentially flat in amplitude over the frequency range shown.

The 12/19/78, 1311 view shows a similar but more complex impulsive noise found at 12th St. and Towne St. The data were taken with the measurement van parked. The upper view shows three distinct amplitude levels for the noise as well as the strongest Loran signal, Y, at about -50 dBm. The bottom view shows a very complex and variable set of spacings between successive impulses. However, all impulses were synchronized to the frequency of the power line. The close spacing and different spacings observed imply that multiple switching devices triggering at different switching points on the voltage cycle were fed by the distribution line. Close examination of the view shows that some slanting lines are distinct while others are less pronounced. The most distinct lines are spaced 8.3 ms apart and are shown as N_1 on the amplitude scale. N_2 and N_3 correspond to other less pronounced lines. 49 separate impulses can be identified across the 100 ms scan period at the threshold setting of -70 dBm used for the bottom view. Thus a Loran receiver operating at this site at this time would receive a separate distinct noise impulse at an average of about every 2 ms.

The 12/18/78, 1303 example shows another case of impulsive noise, along with a decrease in the strength of the Loran-C signals. As the measurement van moved along Hooper, modest noise was encountered just prior to 50th St. A brief and sharp decrease in the noise and the Loran signals occurred at 50th St. followed by slower variations of the noise and signal amplitude along Hooper. These variations were associated with various nearby structures and overhead cables. While the noise amplitude was not as large as shown in previous examples, the signal level decreases caused a poor signal-to-noise situation. The slanting lines of the noise impulses appeared to be spaced further apart than previous examples and their width was not as distinct.

Another examination of the noise at Hooper and 50th made on 12/18/78 at 1510 is shown with an expanded time scale. Multiple users with overlapping impulse times can be seen in the view. The primary noise impulses occurred at 8.3 ms spacings, and other impulses can be seen between the primary lines.

The 12/22/78, 1150 view was taken two blocks further along Hover at 52nd St. A more simplistic type of impulsive noise situation is shown where the impulses were evenly spaced at 16.6 ms intervals. This spacing suggests that a switching device was being fed by the nearby transmission line that operated on only the positive (or the negative) portion of the power line waveform. The pulse amplitude was equal to the strongest Loran-C signal or about -50 dBm.

The scanning receiver was changed from a frequency scanning mode of operation to a fixed frequency mode. The output sampling rate was increased by setting the analog signal scan time to 20 ms in the view at 12/22/78, 1142, and to 10 ms in the views at 12/22/78, 1143. These views show successive A-scope (amplitude-time) views of the individual pulses of a Loran group as well as 16 ms spaced noise impulses. In the top view of the 1142 data, 60 scan lines are shown. In the middle view eight scan lines of data from the upper view were expanded for a more detailed view of possible contamination of a Loran-C pulse group by a noise impulse. In the bottom view, the lower four lines of the middle view are further expanded for a detailed look at the noise spike coincidence with the sixth pulse of the group on line 2. The middle view shows a second coincidence on line 6 at the fifth pulse.

In the view at 1142, noise produced a Loran-like impulse at the start of the pulse group shown on line 3 of the lower view and line 8 of the upper view. The noise impulses provided a ninth pulse at the correct timing.

12/19/78, 1358, Compton at about 53rd St (traveling)
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -10 dbm

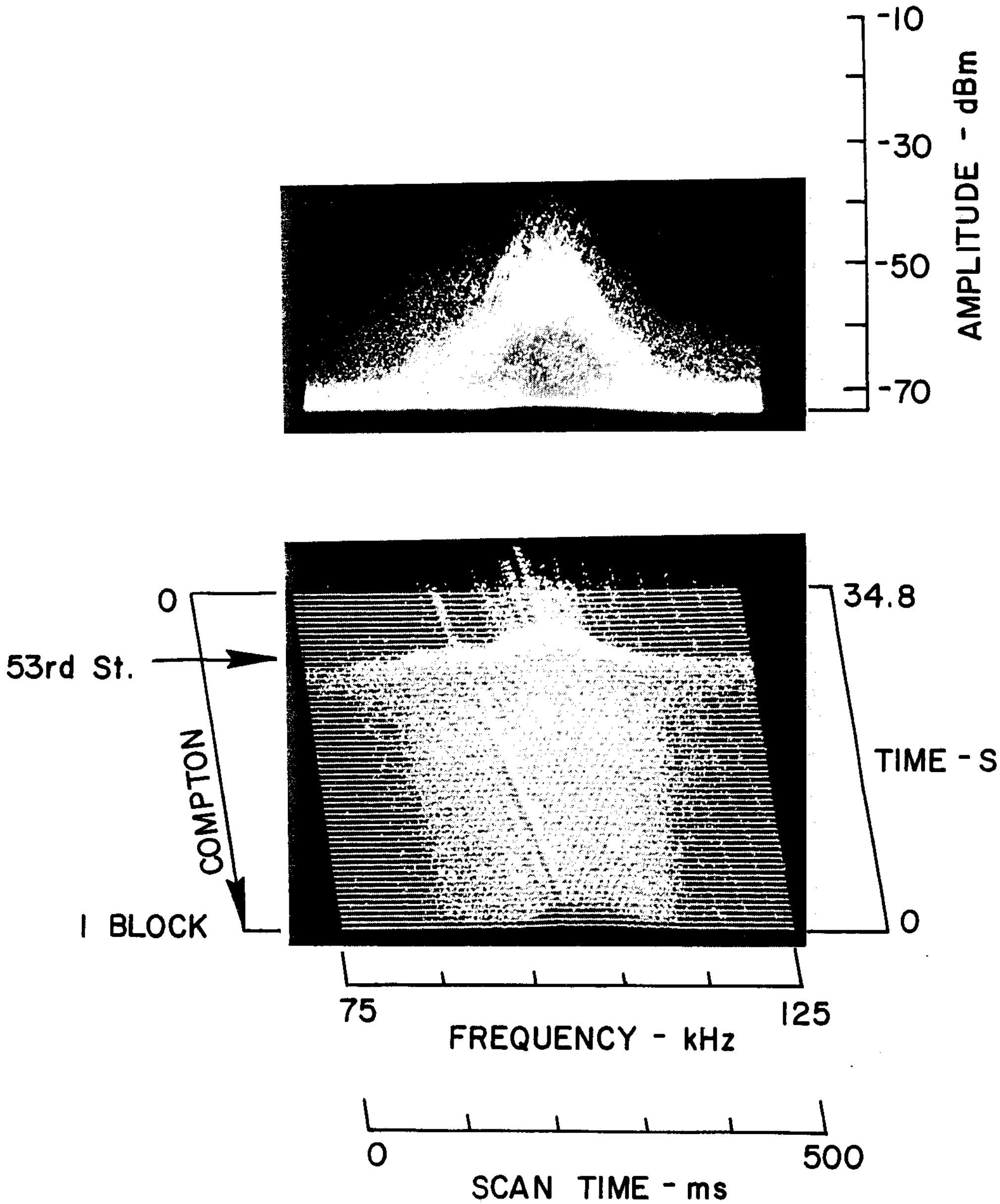


FIGURE 3-3. 12/19/78, 1358

12/19/78, 1311, 12th & Towne (Parked)
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 100 ms, RF 0 dB, IF -10 dbm

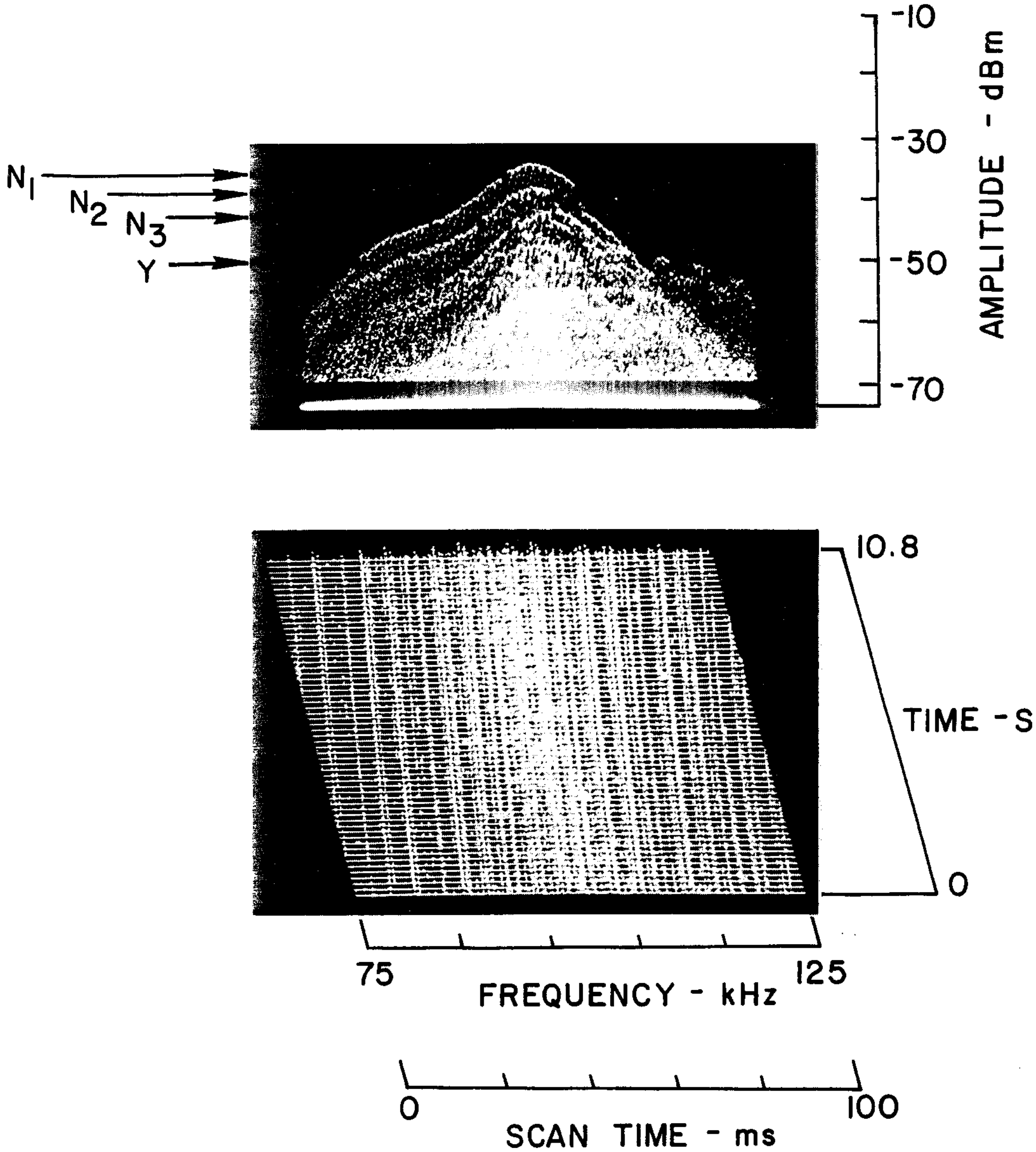


FIGURE 3-4. 12/19/78, 1311

12/18/78, 1303, Hooper & 50th (C16) Moving
HP 140, Whip, F 100 kHz, W 50 kHz, IF 10 kHz, ST 500 ms, RF 0 dB, IF -12 dbm

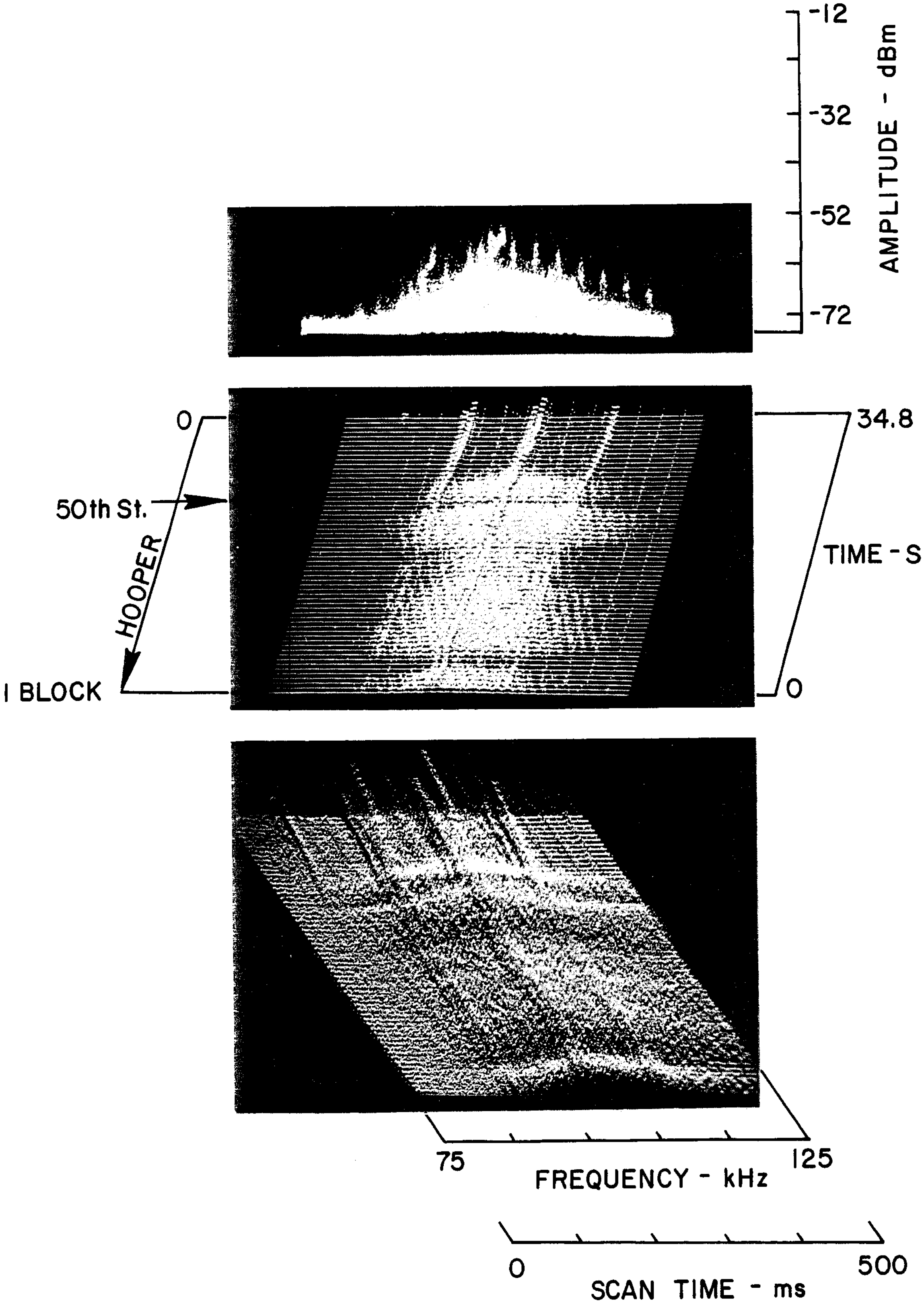


FIGURE 3-5. 12/18/78, 1303

12/18/78, 1510, Hooper & 50th (C16) Parked
HP 140, Whip, F 100 kHz, W 20 kHz, IF 10 kHz, ST 100 ms, RF 0 dB, IF -12 dbm

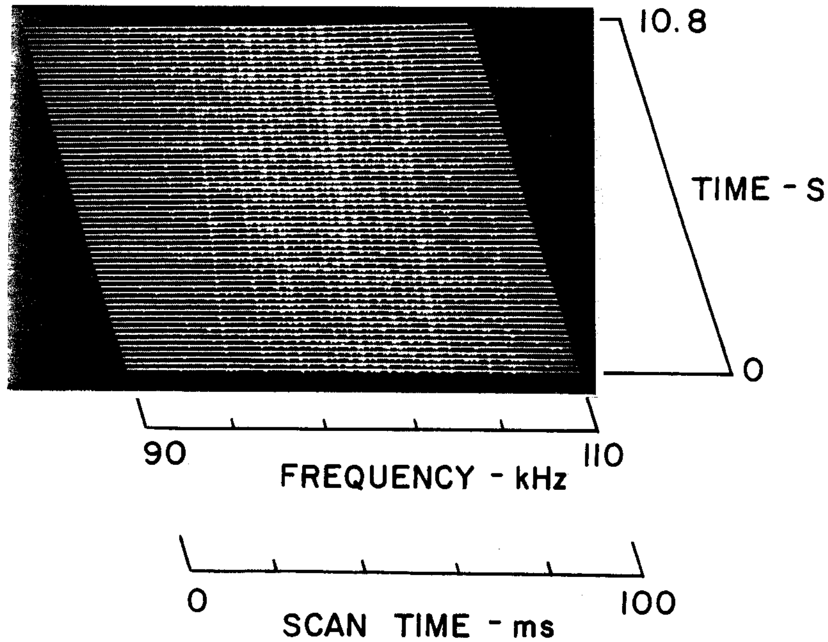


FIGURE 3-6. 12/18/78, 1510

12/22/78, 1150, Hover & 52nd St.
HP 140, Whip, F 100 kHz, W 50 kHz, IF 10 kHz, ST 500 ms, RF 0 dB, IF -20 dbm

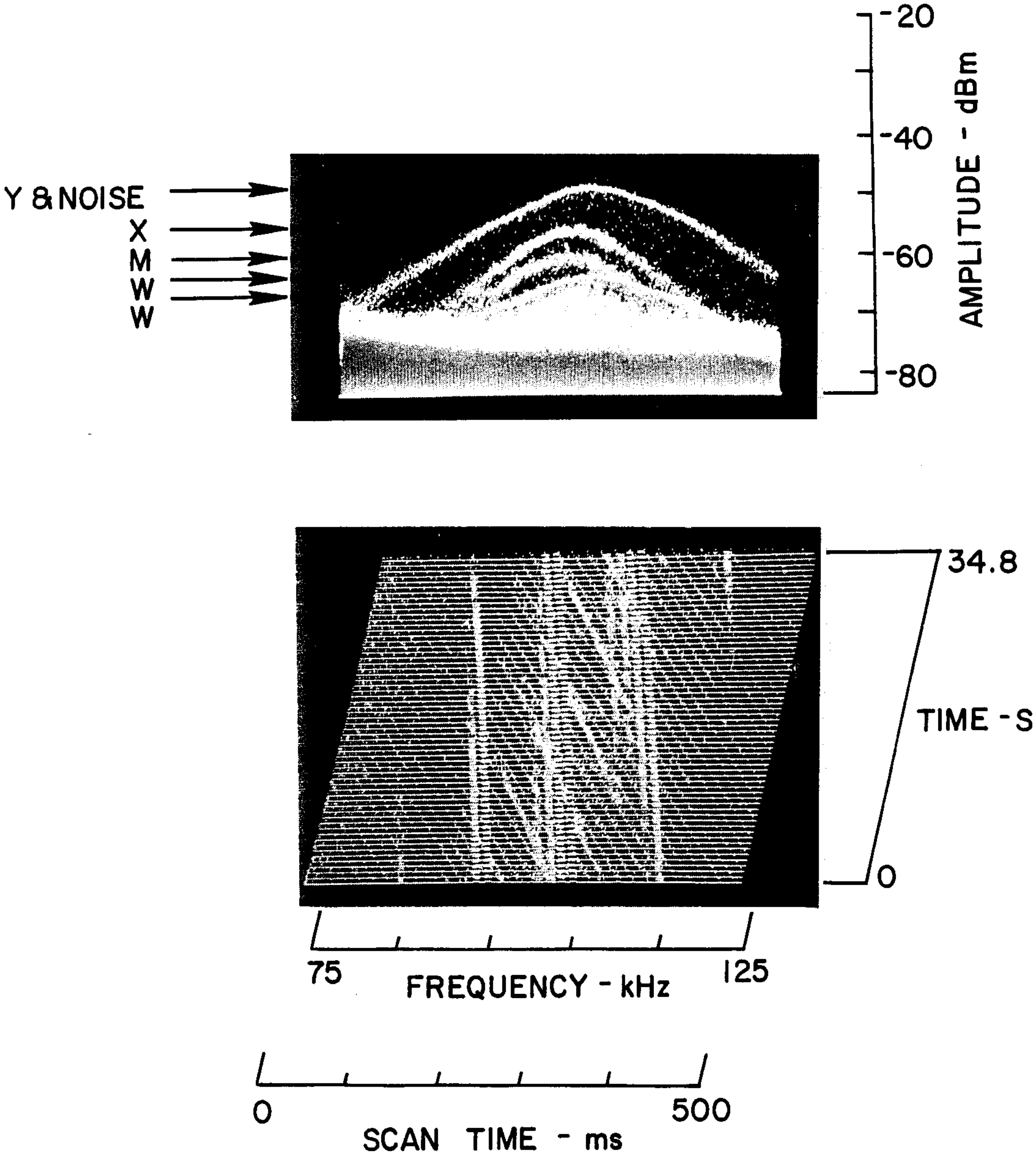


FIGURE 3-7. 12/22/78, 1150

12/22/78, 1142, Hover & 52nd St.
HP 140, Whip, F 100 kHz, W 0-TT, IF 10 kHz, ST 20 ms, RF 0 dB, IF -20 dbm

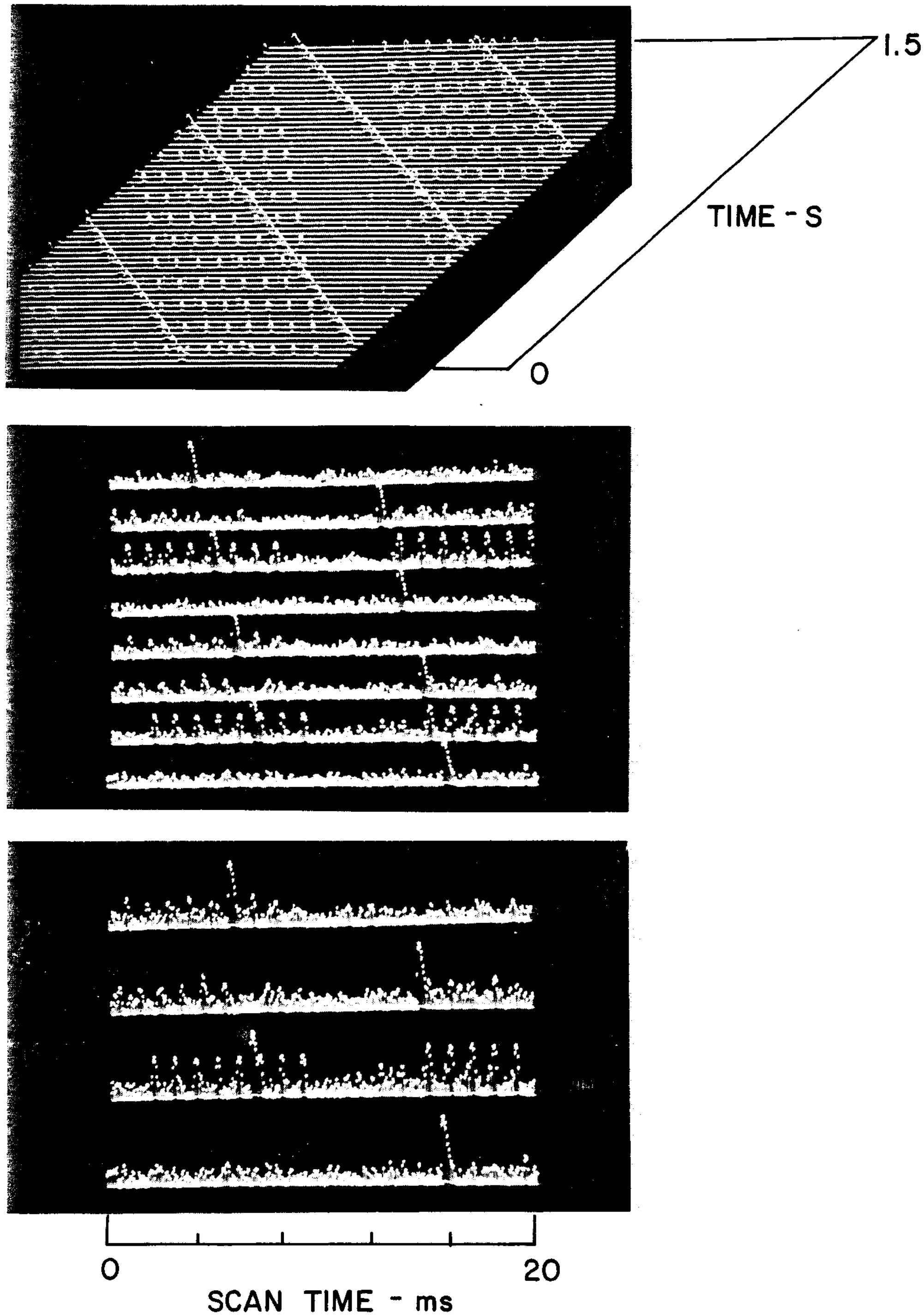


FIGURE 3-8. 12/22/78, 1142

12/22/78, 1143, Hover & 52nd St.
HP 140, Whip, F 100 kHz, W 0-TT, IF 10 kHz, ST 10 ms, RF 0 dB, IF -20 dbm

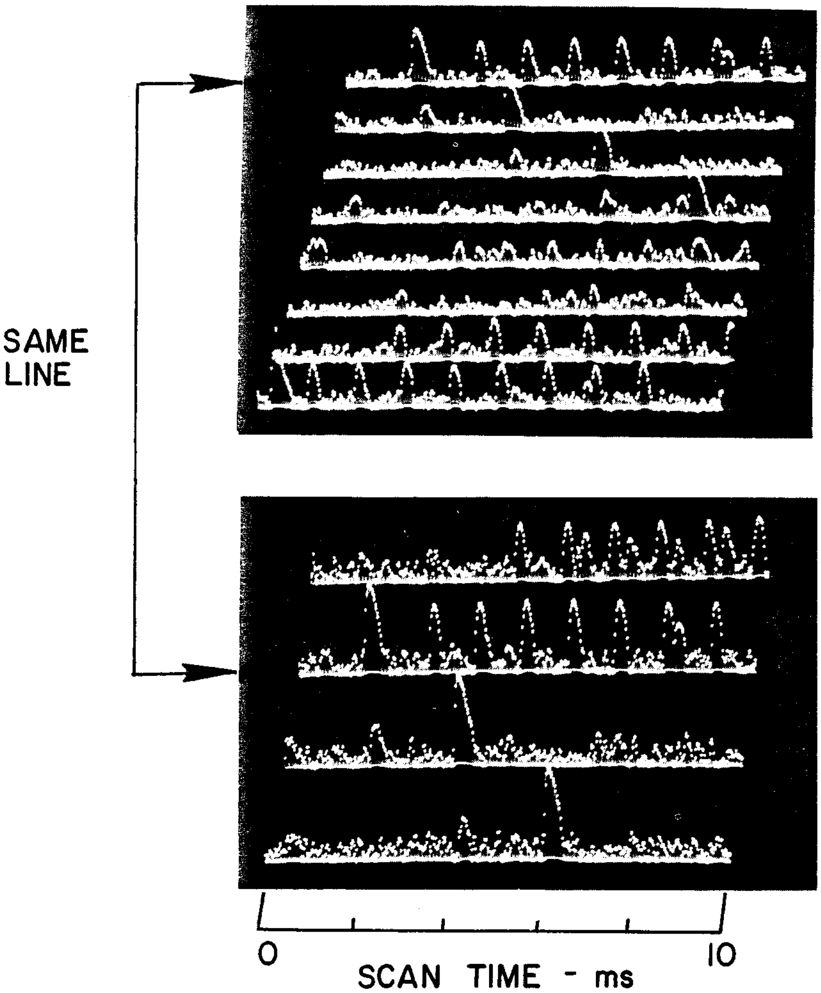


FIGURE 3-9. 12/22/78, 1143

3.4 QUASI-RANDOM NOISE AND MIXED NOISE

Reference 3-Axis Views:		
	12/22/78, 1026	(Figure 3-10)
	12/22/78, 1045(a)	(Figure 3-11)
	12/22/78, 1045(b)	(Figure 3-12)
	12/22/78, 1045(c)	(Figure 3-13)
	12/22/78, 1019	(Figure 3-14)
	12/22/78, 1059(a)	(Figure 3-15)
	12/22/78, 1059(b)	(Figure 3-16)
	12/20/78, 1132	(Figure 3-17)
	12/21/78, 1033	(Figure 3-18)

The above-listed views portray cases of modest to severe quasi-random noise and quasi-random noise mixed with the impulsive noise described in Section 3.2. Again, the views show the general properties of the noise as well as examples of Loran-C signals immersed in the noise. The term quasi-random noise has been used to categorize situations where no distinct and major time or spectral domain properties existed in the noise. The scanning receiver and display controls were employed to search for any distinctive noise features without success.

The 12/22/78, 1026 data obtained at Compton and Slauson shows an example of noise lacking distinctive structure. Loran-C signals are more distinct at the lower frequencies, suggesting that the noise energy slowly increased with frequency. In the upper view two separate noise amplitude levels can be identified in the right portion of the amplitude view. A close examination of the lower view suggests that the stronger noise in that portion of the view was impulsive at a period of 16.6 ms. However, near the center of the frequency scale at 100 kHz, the impulsive noise and the random noise were at about equal amplitudes. Composite noise situations which were not uniform across the bandwidth of the Loran-C signal were noted at several locations.

Another view of the same noise is shown in the 12/22/78, 1045(a) data where the frequency axis was increased to cover a 50 kHz wide block of frequencies. The two distinct types of noise can also be identified in the two views. Also, a CW signal is shown at about 118 kHz. A time-time view of this situation is shown in the 1045(b) data. In the upper view the amplitude threshold control has been carefully adjusted to show peaks of the Loran-C pulses. The threshold control was lowered a few dB in the bottom view and the noise contamination was sufficiently severe that visual signal identification was extremely difficult. In the top view of the 1045(c) data, eight scan lines of data from 1045(b) were expanded. Pulse groups from station Y can be seen on lines 1 and 8. A pulse group from station X is on line 2. The bottom four lines of the upper view are further expanded in the bottom view. The noise severely distorted the Loran-C pulses and exceeded all Loran stations in amplitude except for Y signals which were received at a very low signal-to-noise margin.

Data at the same location at other times were taken which showed somewhat different noise properties. The views of 12/22/78, 1019, show a mixture of random noise and impulsive noise with a spacing of about 8 ms. The 12/22/78, 1059(a) data show a period when the impulsive noise increased in level and dominated the random noise. In the upper view the threshold control was adjusted to show Loran-C peak pulse amplitudes. The impulsive noise also exceeded this amplitude. In the bottom view the threshold control was lowered to include the random noise. The 1059(b) data show expanded time views. Eight lines are shown in the upper two views where the threshold control was set at zero. Loran-C signals from station Y, impulses, and random noise are shown. In the middle view, the threshold control was adjusted to the level of the top view of 1059(a). The first four lines are shown with further detail in the bottom view where considerable signal distortion is evident, as well as a coincidence between the eighth pulse and a noise impulse.

Another view of quasi-random noise is shown in the 12/20/78, 1132 data. Loran-C signal levels exceed the noise in the lower portion of the frequency range but are equal to the noise level in the upper frequencies. Noise contamination from the ignition system of a 110 volt gasoline generator is shown at a level about 5 dB above the Loran-C and noise signal.

A view of the onset of quasi-random noise as the instrumentation van approached a distribution line at Grand St. and 45th St. is shown in the data for 12/21/78, 1033. Prior to 45th St. Loran-C signals were received very well. Within a few feet of travel the noise peaks increased in level to roughly equal that of the Y signal.

12/22/78, 1026, Compton & Slauson
HP 140, Whip, F 100 kHz, W 20 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -10 dbm
Two insulator distribution lines along Compton from Slauson to 53rd St.
Noise similar along Compton

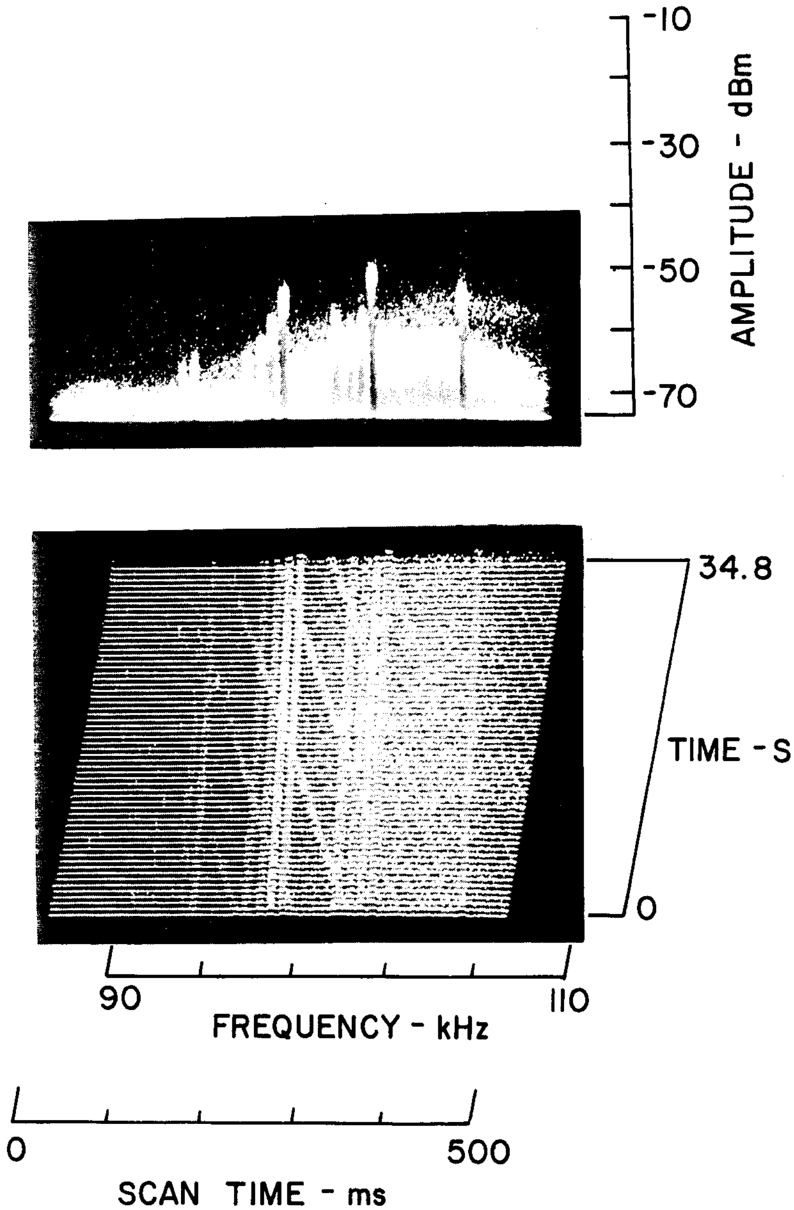


FIGURE 3-10. 12/22/78, 1026

12/22/78, 1045(a), Compton and Slauson
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -10 dbm

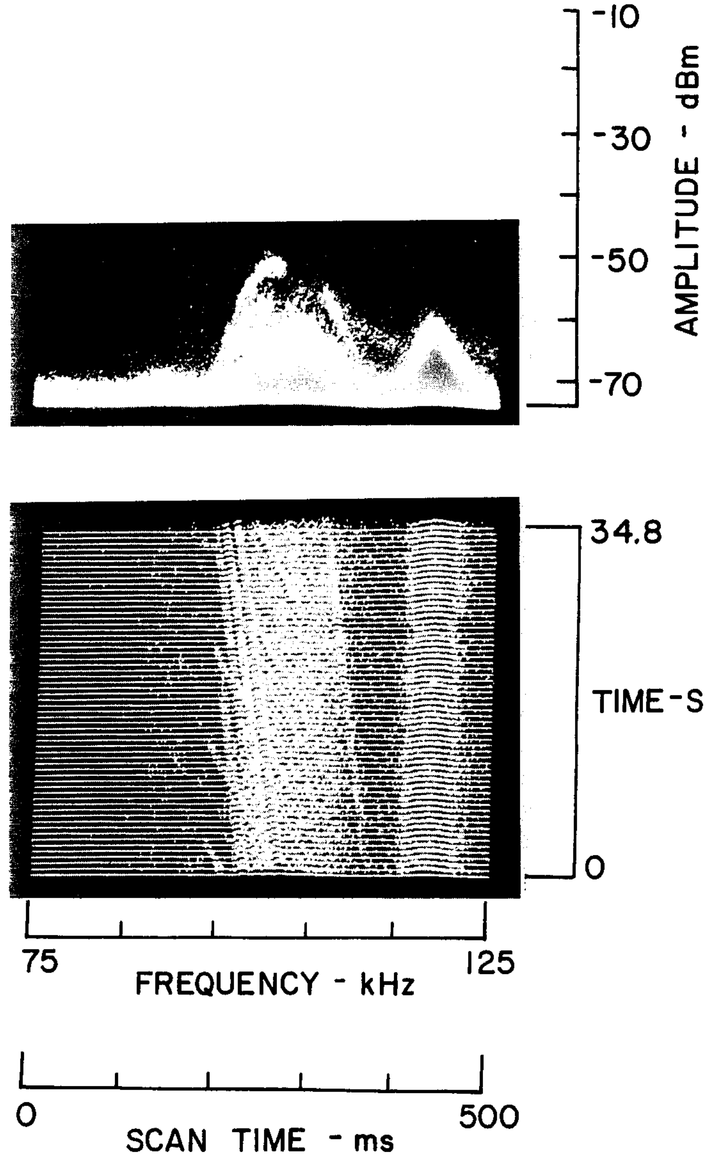


FIGURE 3-11. 12/22/78, 1045(a)

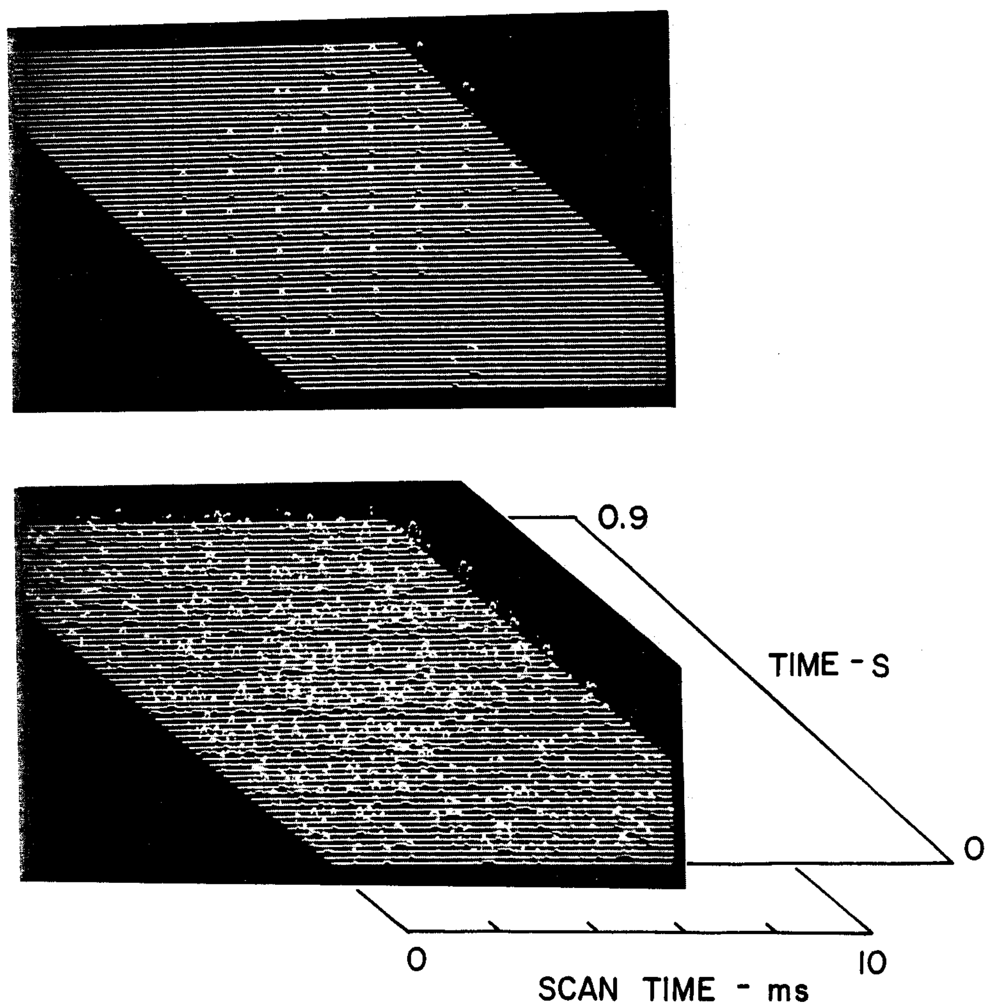


FIGURE 3-12. 12/22/78, 1045(b)

12/22/78, 1045(b), Compton and Slauson
HP 140, Whip, F 100 kHz, W 0-TT, IF 10 kHz, ST 10 ms, RF 0 dB, IF -10 dbm

12/22/78, 1045(c), Compton and Slauson
HP 140, Whip, F 100 kHz, W 0-TT, IF 10 kHz, ST 10 ms, RF 0 dB, IF -10 dbm

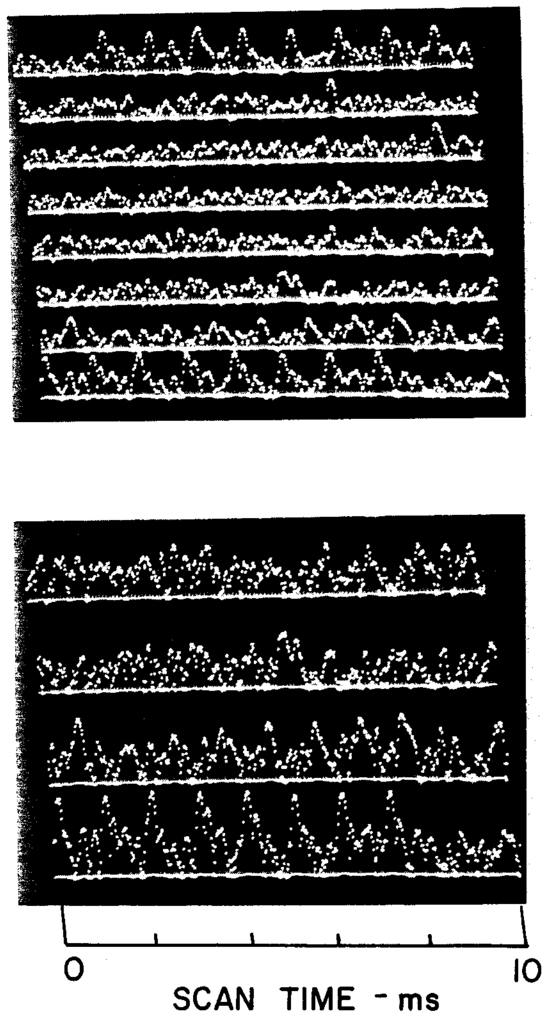


FIGURE 3-13. 12/22/78, 1045(c)

12/22/78, 1019, Compton & Slauson
HP 140, Whip, F 100 kHz, W 0-TT, IF 10 kHz, ST 20 ms, RF 0 dB, RF 0 dB, IF -10 dbm

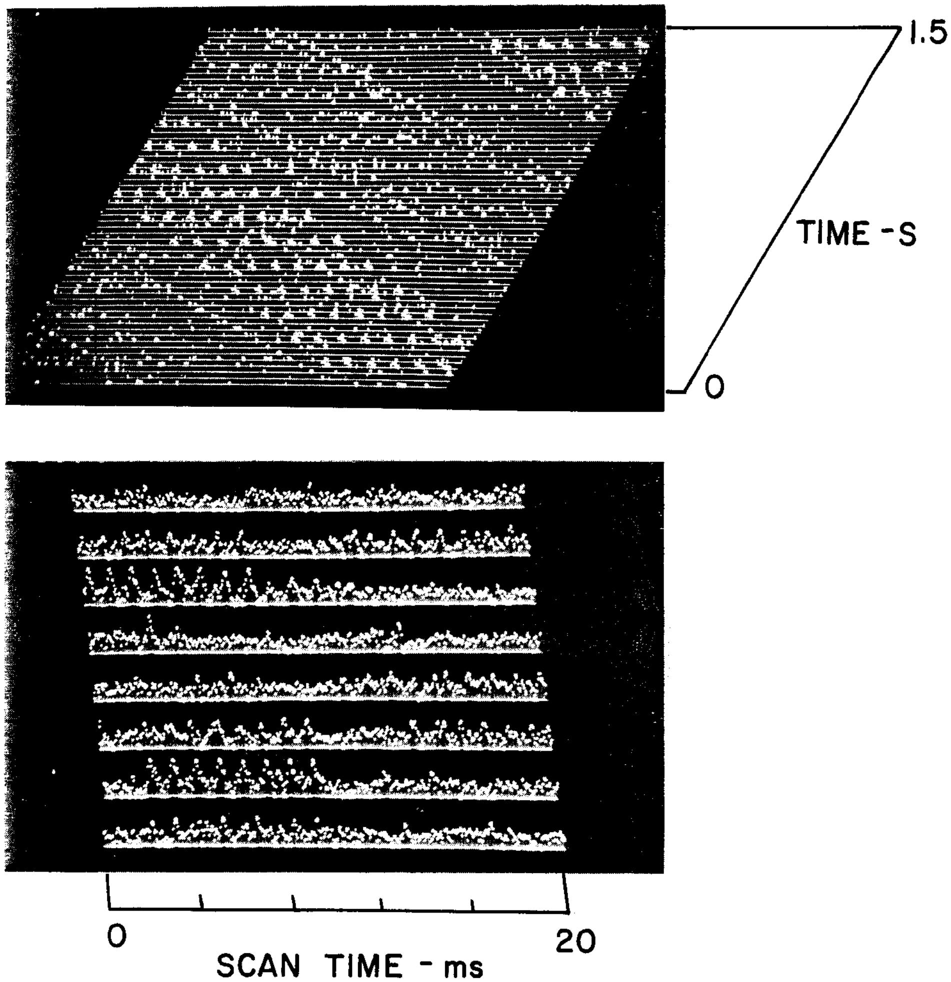


FIGURE 3-14. 12/22/78, 1019

12/22/78, 1059(a), Compton and Slauson
HP 140, Whip, F 100 kHz, W 0-TT, IF 10 kHz, ST 20 ms, RF 0 dB, IF -10 dbm

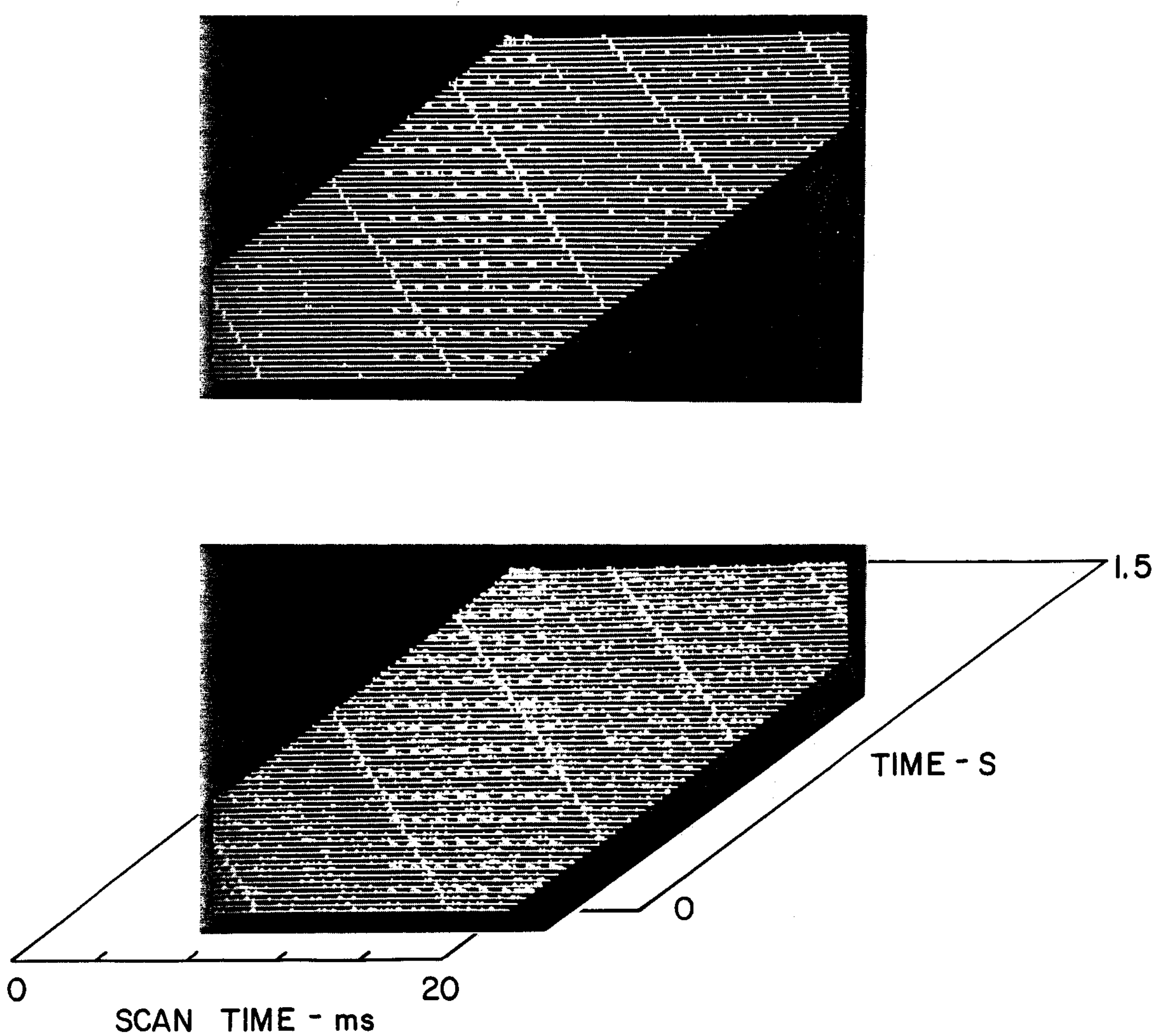


FIGURE 3-15. 12/22/78, 1059(a)

12/22/78, 1059(b), Compton and Slauson
HP 140, Whip, F 100 kHz, W 0-TT, IF 10 kHz, ST 20 ms, RF 0 dB, IF -10 dbm

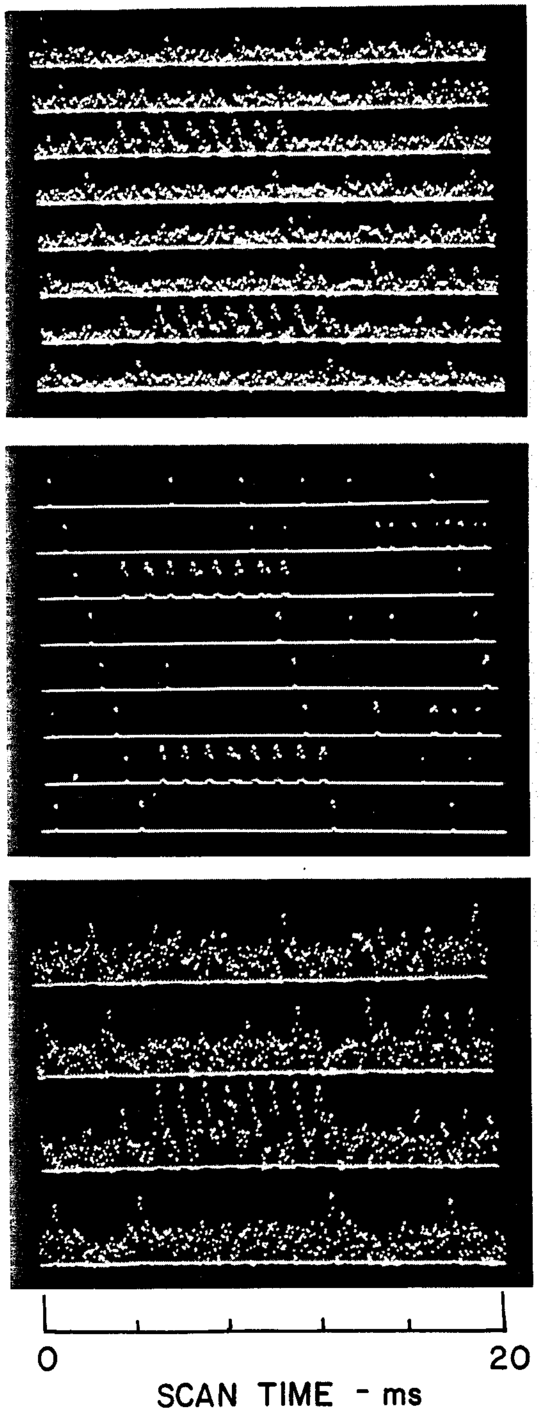


FIGURE 3-16. 12/22/78, 1059(b)

12/20/78, 1132, Exposition at Gramercy (parked)
HP 140, Whip, F 100 kHz, W 20 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -10 dbm
Noise along Exposition until about Arlington

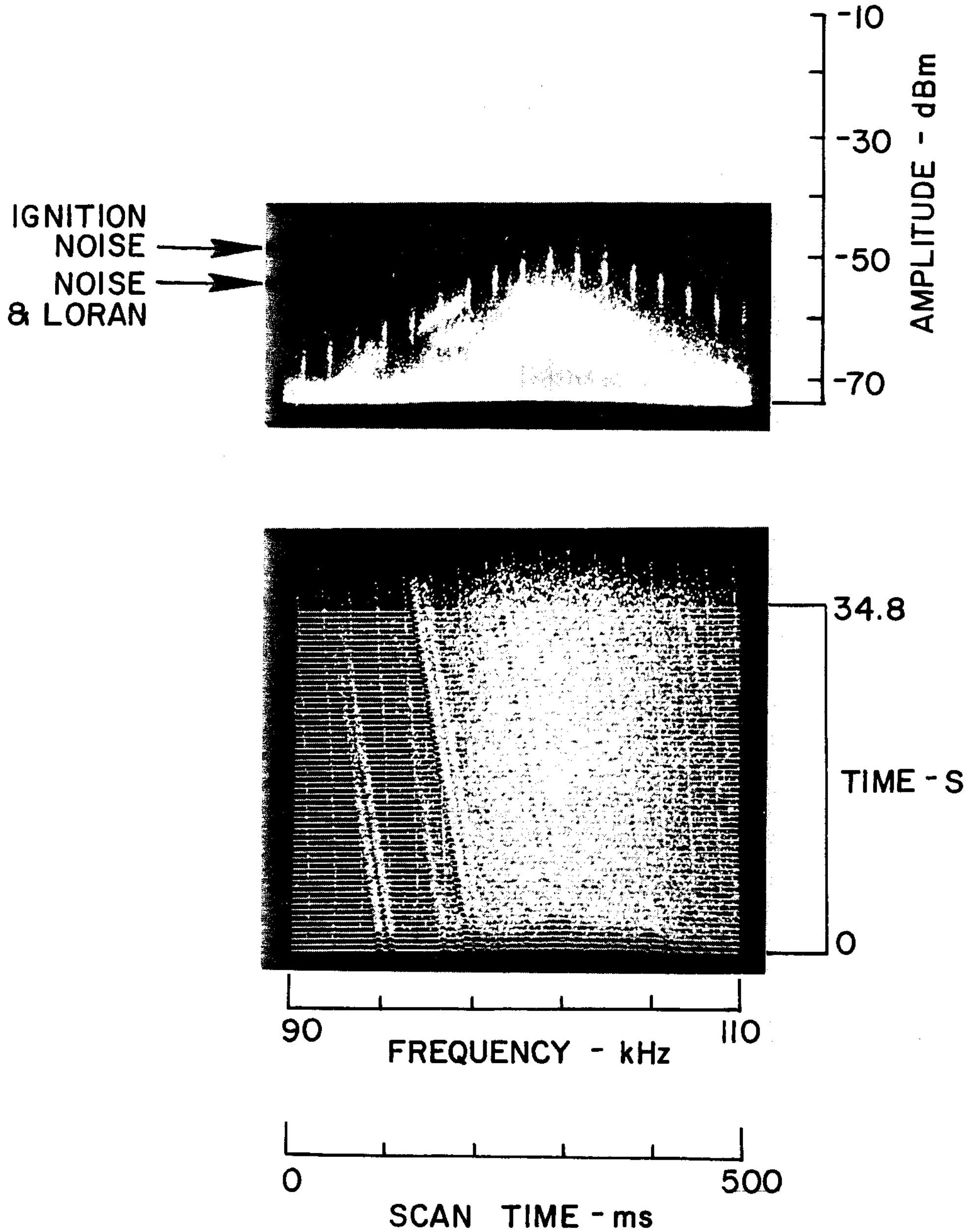


FIGURE 3-17. 12/20/78, 1132

12/21/78, 1033, Grand & 45th St. (moving)
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -20 dbm

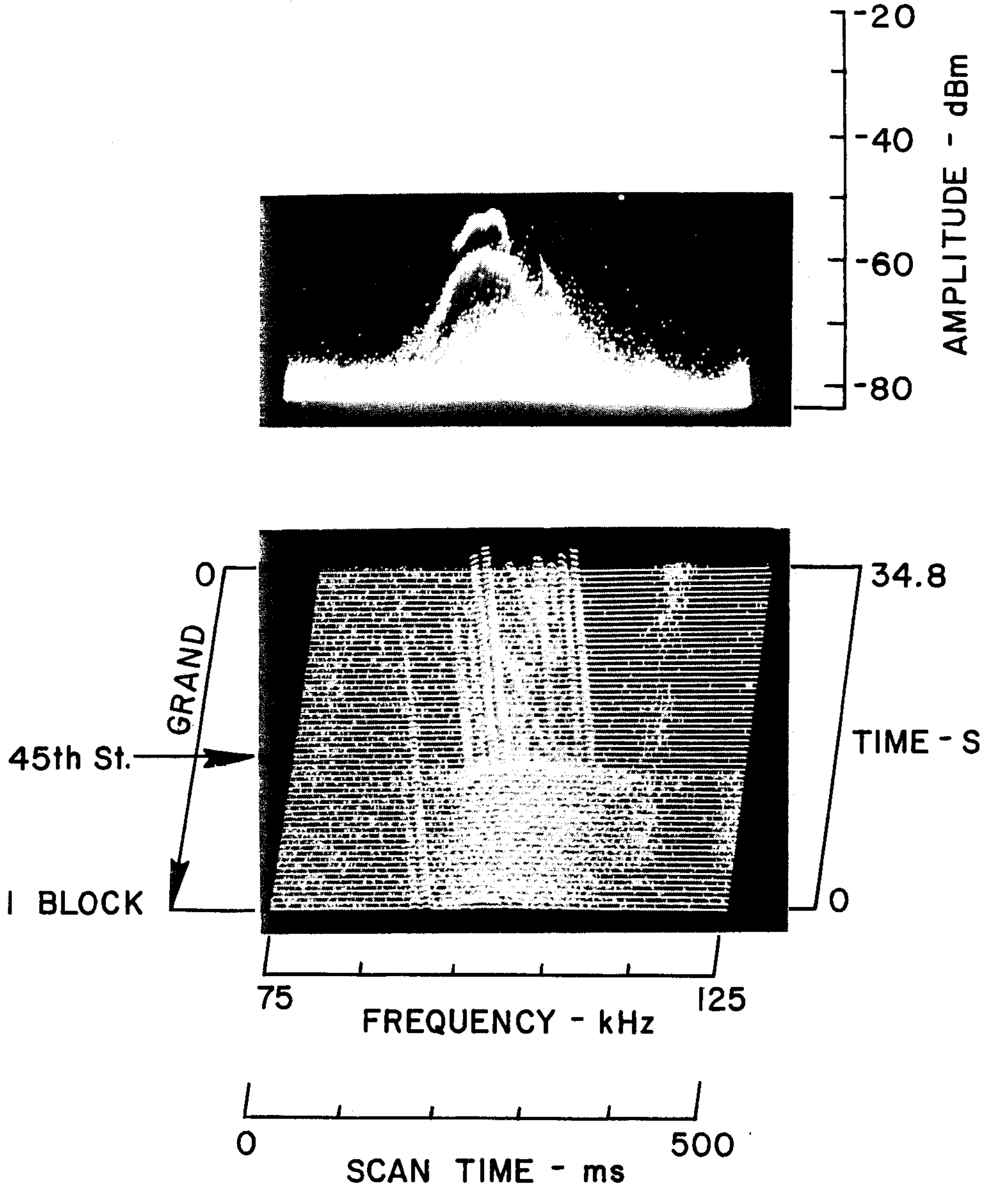


FIGURE 3-18. 12/21/78, 1033

3.5 STRONG LOCAL AREA NEAR FIELD SIGNALS

Reference 3-Axis Views: 12/21/78, 1130 (Figure 3-19)
12/20/78, 1407 (Figure 3-20)
12/19/78, 1543 (Figure 3-21)
12/21/78, 1135 (Figure 3-22)
12/20/78, 1400 (Figure 3-23)

The 12/21/78, 1130 data show a typical example of strong local area CW signals. These signals abruptly rise from below receiver noise levels to very strong signal levels in a few tens of feet. In the 1130 example four distinct CW signals appeared simultaneously at about 75, 92, 108, and 124 kHz and very rapidly increased in amplitude, and the 108 kHz signal rose to a level equal to the Loran Y signal. The four signals decreased in level and disappeared below the receiver threshold level as abruptly as the increase. The location of the signal source is obviously at Trinity and 22nd St. but the precise source was not firmly established. Inspection of the area did not reveal a specific box labeled "LF oscillator."

Another example is shown in the data taken at 12/20/78, 1407, where six separate and discrete frequency CW signals appeared in the 3-axis view and rose to a maximum in about 100 feet of travel along Halldale. The maximum signal appeared at the corner of Halldale and Vernon. The 77, 92, 109, and 123 kHz signals are very similar to those in the previous example at 12/21/78, 1130. A weak 100 kHz signal can be seen in the upper view directly under the maximum peak of the Loran-C Y signal. The 117 kHz signal amplitude did not vary in amplitude with the others, and it was observed at many other locations unassociated with the strong local area signals. The 117 kHz signal is believed to be an LF communications signal from a distant transmitter. The source of the local area signal was again not obvious.

A third example of local area CW signals is shown in the data for 12/19/78, 1543. Discrete frequencies of 93, 102, 108, 118, and 123 kHz were observed where the 93, 108, and 123 kHz signals were classified as local area. These signals were associated with overhead unshielded telephone wires; however, precise location equipment was not used to firmly verify this association. No other obvious sources were found in an inspection of the area.

Another somewhat different observation of the 92 and 108 kHz CW signals previously classified as of the local area type is shown in the data for 12/21/78, 1135. The signals abruptly appeared but remained in the 3-axis view for an entire block. The consistent and rapid fading of both signals suggest that they are from the same source and that the source is on 25th St. near Trinity. However, the radiation mechanism must involve wires along 25th St. Brief bursts of signal at 123 kHz can also be seen which coincide with amplitude peaks in the 92 and 108 kHz signals which further suggest that the source mechanism is similar to that of the previous examples.

Another example of local area CW signals is shown in the data at 12/20/78, 1400. Also shown in the view is noise typical of that emitted from power lines with electrical leakage along insulators. The local area signal at about 108 kHz and the power line noise were about equal in amplitude to the Loran-C Y signal, while the 92 kHz signal was about 10 dB below the Y signal amplitude.

12/21/78, 1130, Trinity at 22nd St. (moving slowly)
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -20 dbm

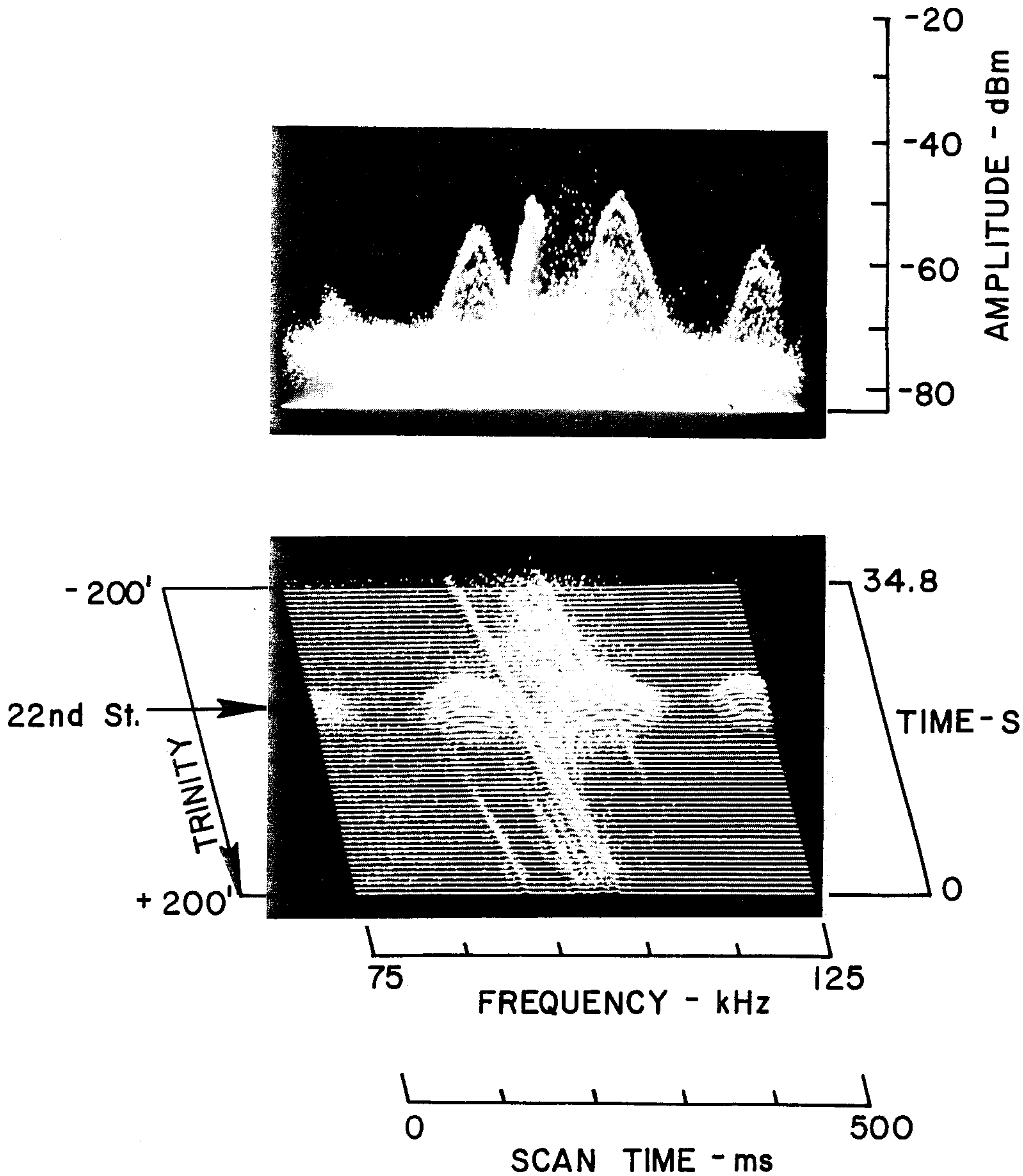


FIGURE 3-19. 12/21/78, 1130

12/20/78, 1407, Halldale at Vernon (moving slowly)
HP 140, Whip, F 100 kHz, W 50 kHz, IF 1 kHz, ST 100 ms, RF 0 dB, IF -20 dbm

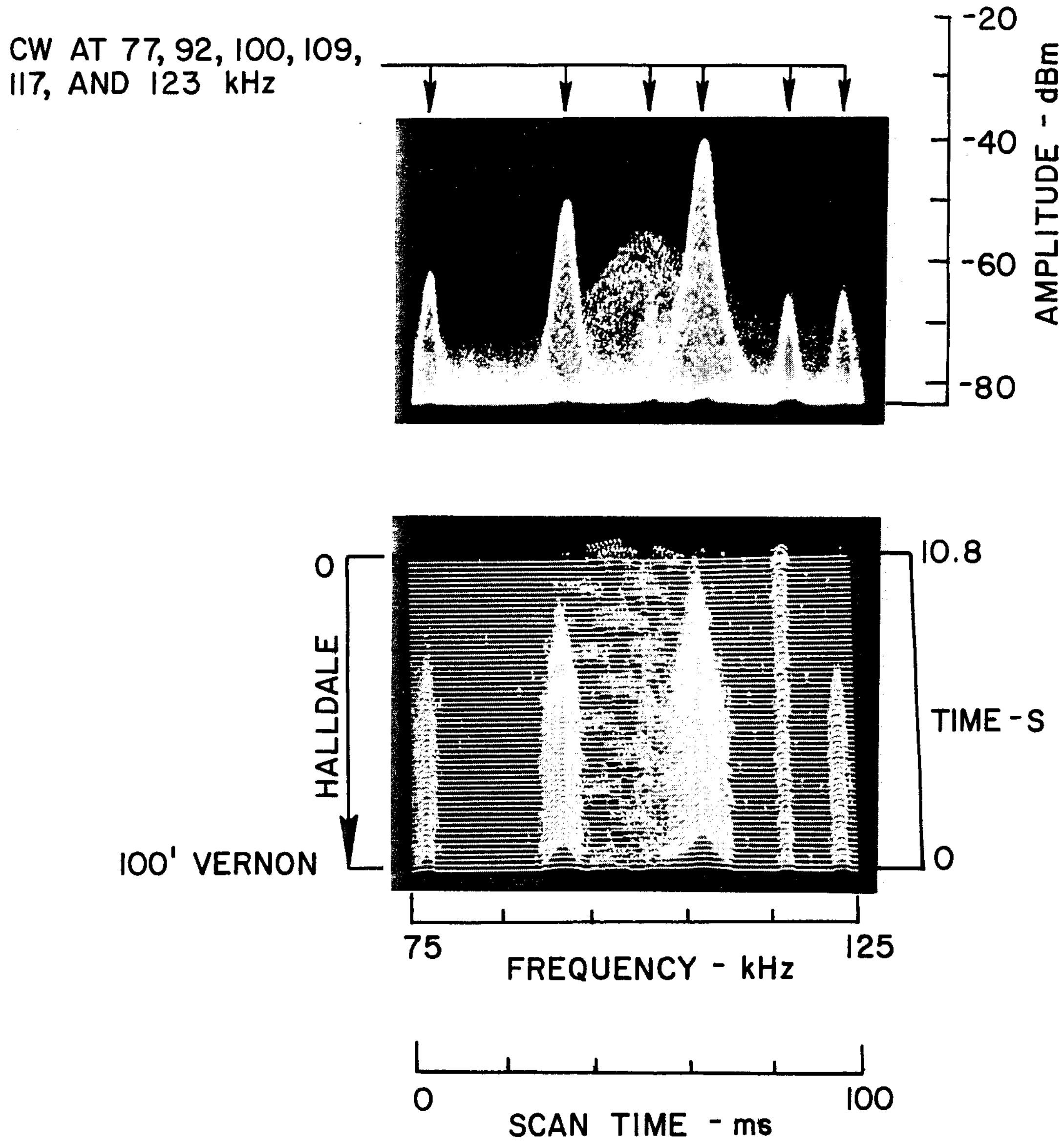


FIGURE 3-20. 12/20/78, 1407

12/19/78, 1543, 46th St. and turn left on McKinley
HP 140, F 100 kHz, W 50 kHz, IF 1 kHz, ST 100 ms, RF 0 dB, IF -38 dbm

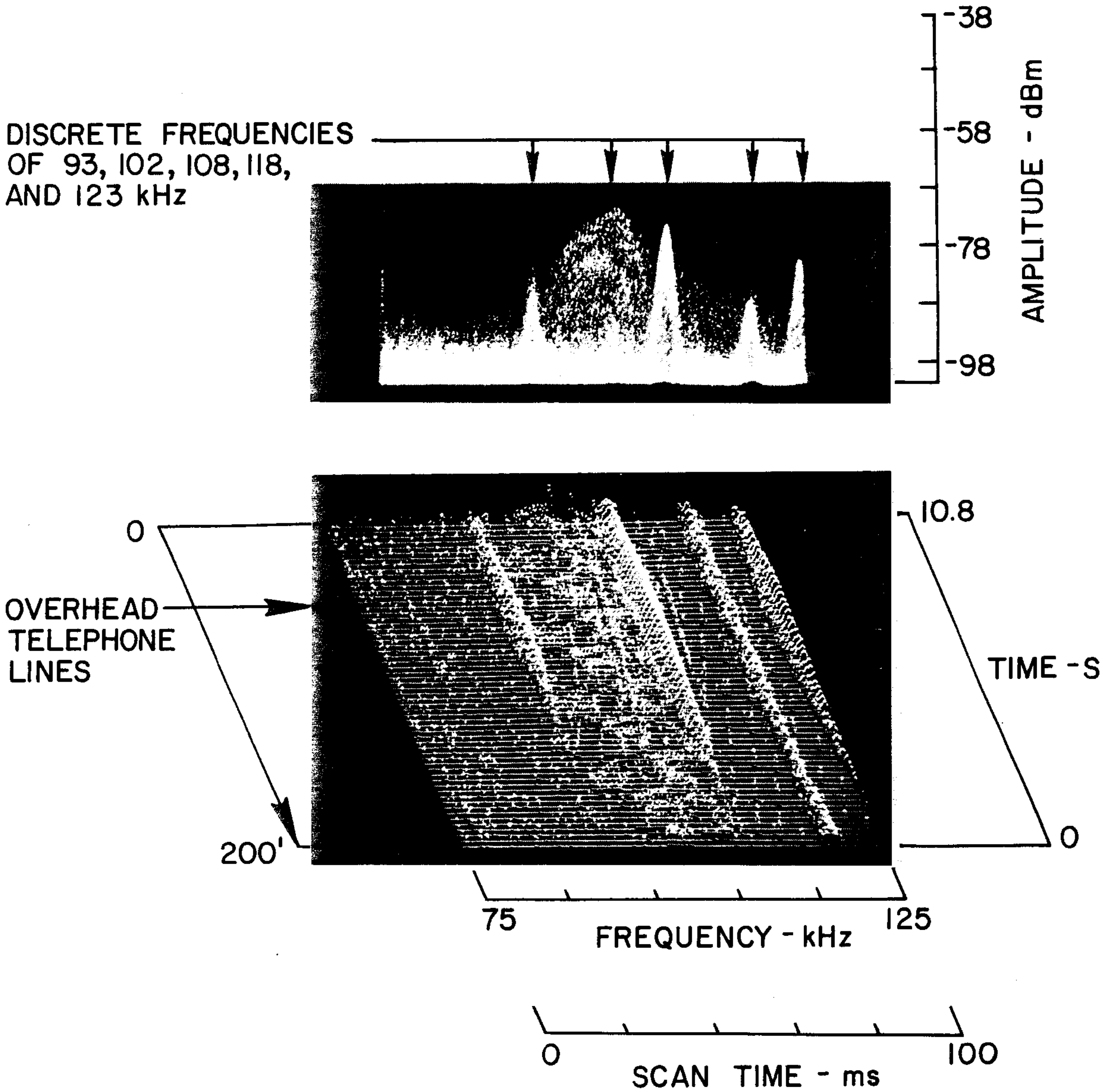


FIGURE 3-21. 12/19/78, 1543

12/21/78, 1135, 25th St. between Trinity and Maple
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -20 dbm

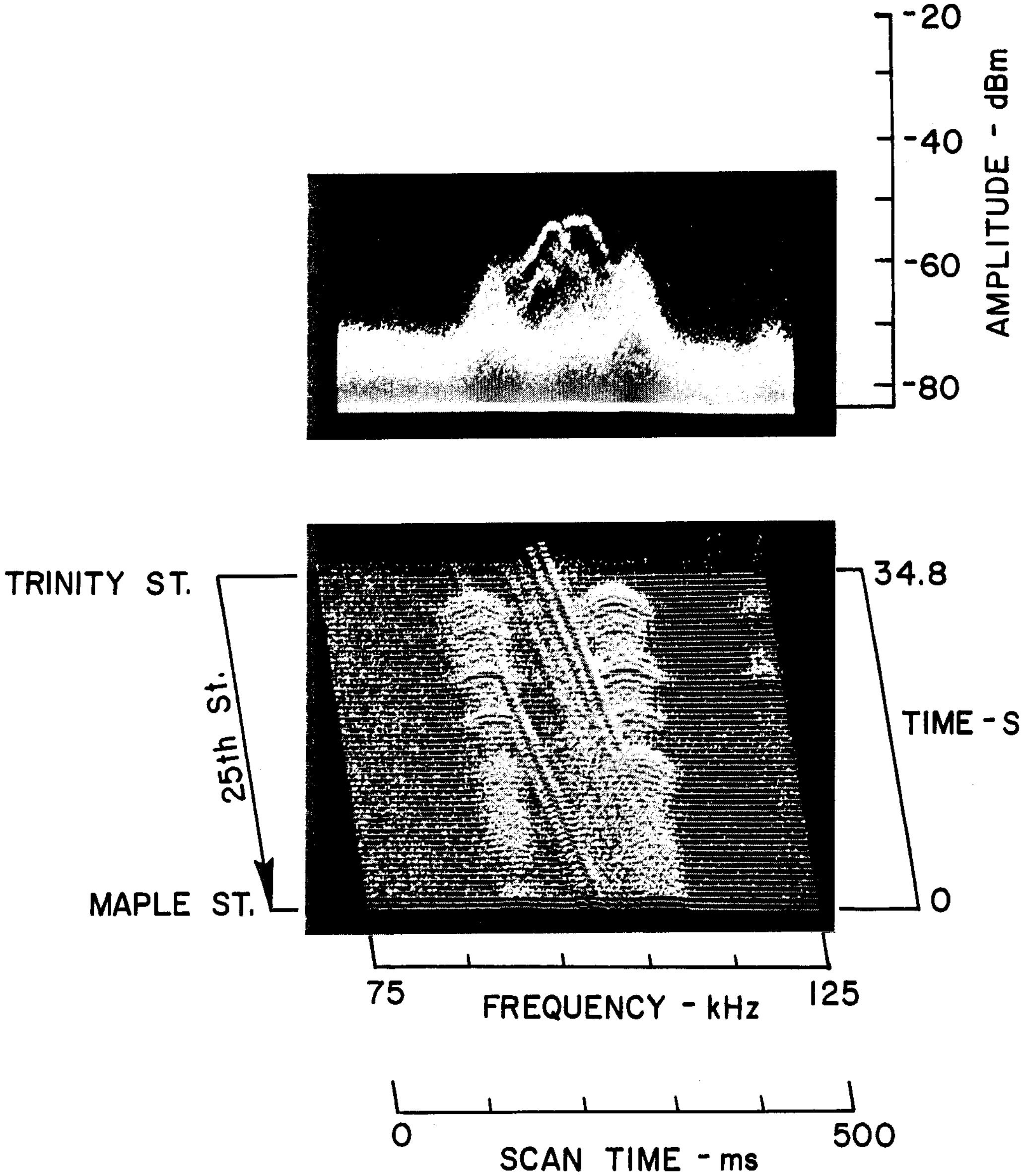


FIGURE 3-22. 12/21/78, 1135

12/20/78, 1400, Vernon & Dalton (moving)
HP 140, Whip, F 100 kHz, W 20 kHz, IF 3 kHz, ST 100 ms, RF 0 dB, IF -10 dbm

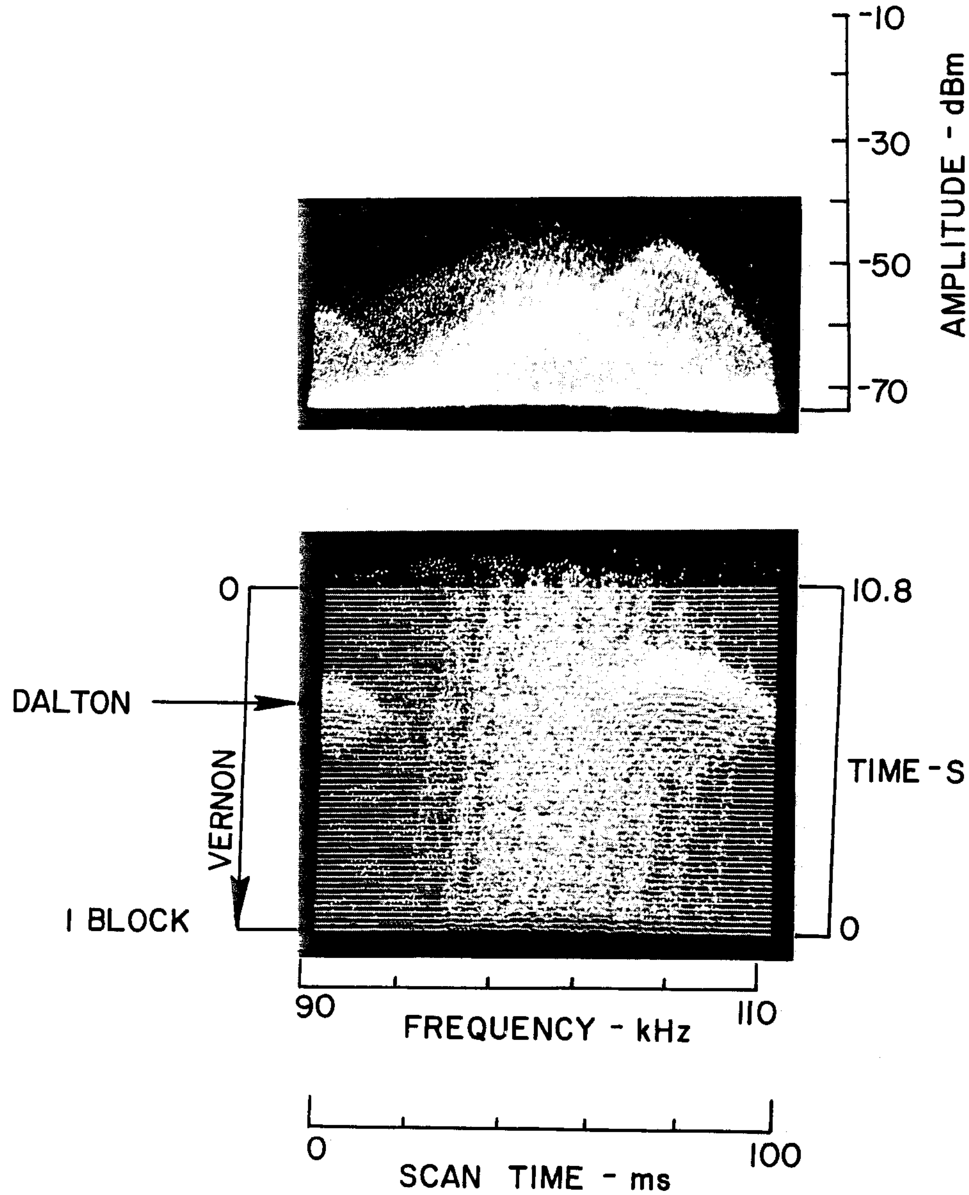


FIGURE 3-23. 12/20/78, 1400

3.6 WEAK LARGE AREA SIGNALS

Reference 3-Axis Views: 12/21/78, 0936 (Figure 3-24)
12/21/78, 1500 (Figure 3-25)

Weak CW signals were received at many of the measurement locations. These signals were detectable with the measurement system over large areas of Los Angeles. They also fell below the measurement sensitivity of the system in some areas. The 12/21/78, 0936 measurements show six low level CW carriers in the 50 to 150 kHz band during a morning system check-out at the Los Angeles Coliseum. Signals were found at about 100, 103, 120, 130, 140, and 150 kHz. The system sensitivity was improved for this measurement, compared to most other measurements described in this report, by employing a 0.3 kHz IF bandwidth.

Another measurement of low level CW signals was made on 12/21/78, 1500, which detected weak signals at about 88, 104, 116, and 120 kHz. A 100 kHz calibration signal is shown on the upper six lines of the 1500 3-axis view. The IF bandwidth used for this measurement was 1 kHz.

Similar weak CW signals could be detected at a large number of the measurement sites by merely adjusting the IF bandwidth of the scanning receiver to a very narrow value and employing the increased CW signal detection capability to search for such signals. Loran-C signals and noise were severely attenuated by the narrow IF bandwidth; thus, narrow IF bandwidths were not normally employed for most measurements.

12/21/78, 0936, Coliseum
HP 140, Whip, F 100 kHz, W 100 kHz, IF 0.3 kHz, ST 500 ms, RF 0 dB, IF -40 dbm
Search for weak CW signals

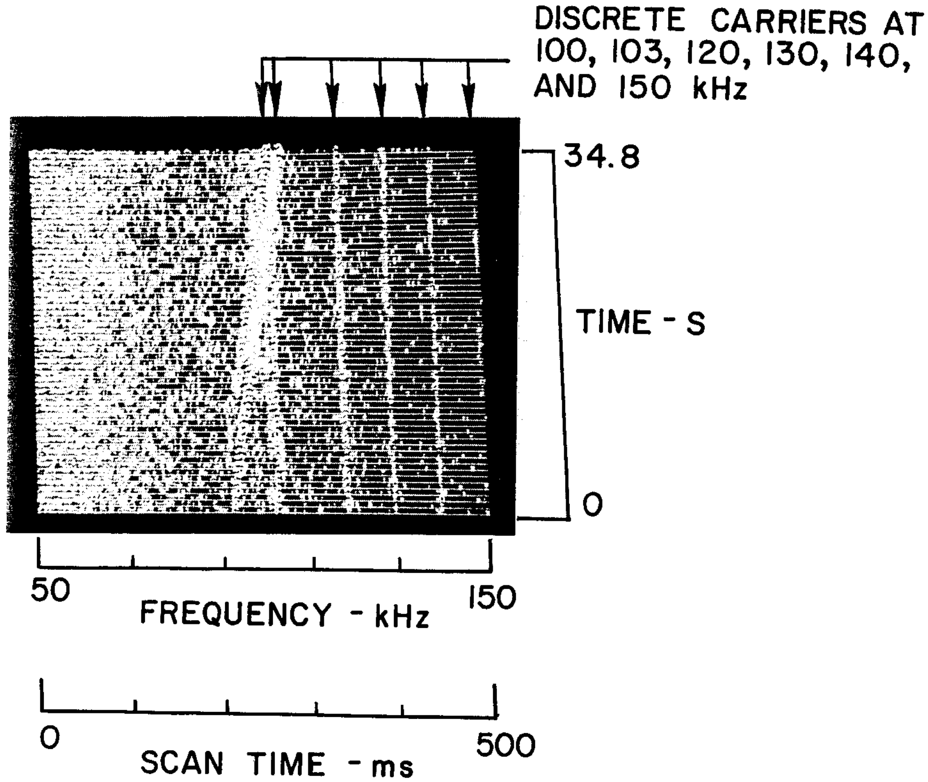


FIGURE 3-24. 12/21/78, 0936

12/21/78, 1500, Broadway & Alpine
HP 140, Whip, F 100 kHz, W 50 kHz, IF 1 kHz, ST 500 ms, RF 0 dB, IF -20 dbm

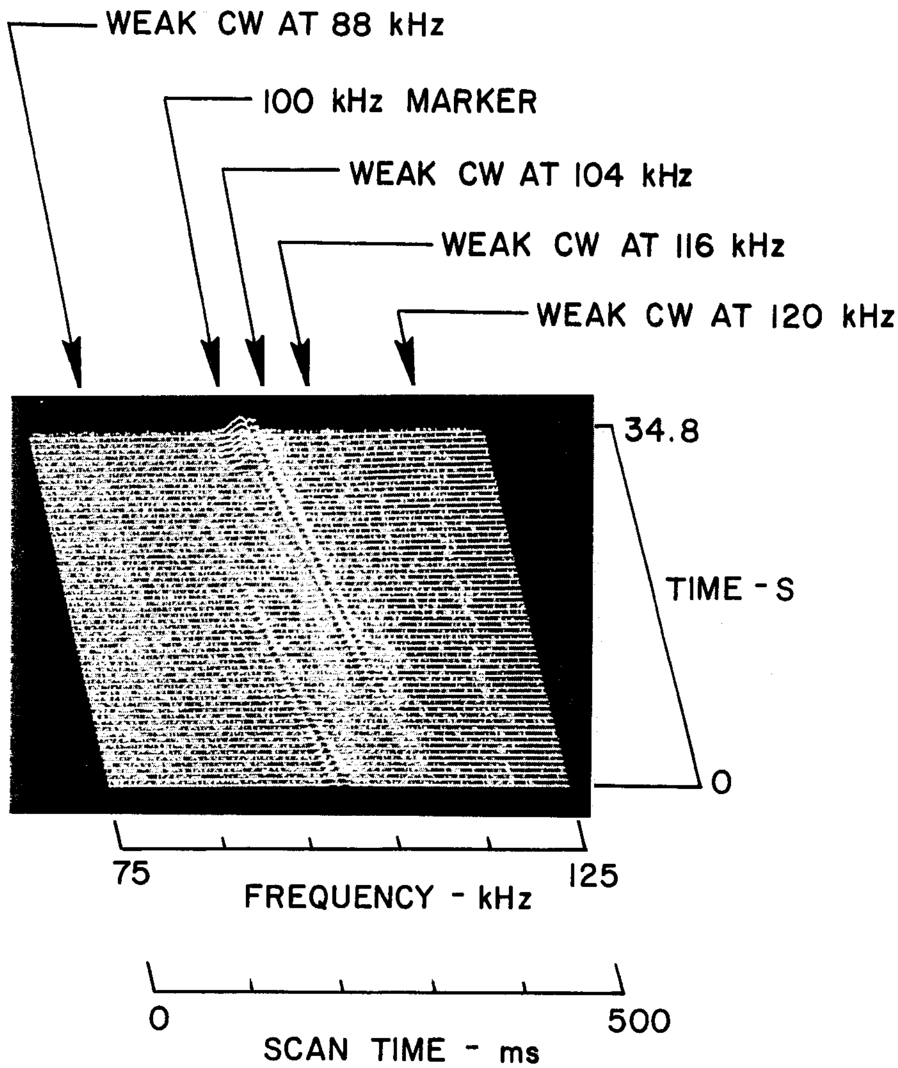


FIGURE 3-25. 12/21/78, 1500

3.7 POWER TRANSMISSION LINE CARRIER COMMUNICATIONS

Reference 3-Axis Views: 12/21/78, 1356 (Figure 3-26)
12/21/78, 1420 (Figure 3-27)
12/21/78, 1520 (Figure 3-28)
12/21/78, 1525 (Figure 3-29)

The electric power utilities employ VLF and LF frequencies in carrier communications systems. Usually such systems are used on high voltage transmission lines for power switching and control purposes. Very few carrier systems are used on utility distribution systems, although occasionally a utility will conduct special measurements or technical tests using a particular distribution line. While no signals could be associated with power line carrier communications on Los Angeles electric utility distribution lines, a specific case was identified on a very high voltage transmission line as shown at 12/21/78, 1356. A discrete CW power carrier was identified at 100 kHz as the line was approached while driving on Artesia Freeway. A very sudden increase in signal level occurred when the measurement van passed directly under the transmission line where the 100 kHz signal was about +15 dB above the Loran Y signal. Very strong but infrequent noise impulses were also noted under the line which were about 25 dB above the Y signal.

A second measurement of the power carrier signal was made about four blocks from the transmission line as shown in the data at 12/21/78, 1420. The narrow bandwidth of the receiver IF suppressed the amplitude of the Loran-C and the impulsive signals in the view by about 10 dB which resulted in a Loran Y signal strength of about 5 dB above the 100 kHz CW power carrier signal. The impulsive noise shown in the view originated from a local distribution line and was about 5 dB above the Y signal amplitude. This mixture of power carrier and impulsive noise was found throughout the light industrial area in the vicinity of Victoria St. and Main St.

Another suspected case of power carrier RFI was investigated on a second high voltage transmission line. The data taken at 12/21/78, 1520, show the complex signals observed on North Spring as the measurement van passed over a complex set of rail lines and under a transmission line. A number of discrete CW signals were found which were too low in amplitude for power carrier on the transmission line. One signal at 96 kHz could have been a power carrier signal since it peaked in level directly under the transmission line. However, it also peaked directly over a number of railroad cables, lines, and facilities. Signals of lower levels at 86, 116, and 122 kHz also had maximum values directly under the transmission line and directly over the railroad facilities. A wideband ($\approx$ 10 kHz wide) signal at about 104 kHz was noted which was better defined by decreasing the scan time from 100 to 200 ms as shown in the data at 12/21/78, 1525. From these views the signal was determined to be FM modulated at a 200 Hz rate with a deviation of about 50. This unusual signal originated from some nearby source since it was not observed on either side of the North Spring railroad overpass.

While the signals in 12/21/78, 1520 and 12/21/78, 1525 are shown in the section on power transmission line carrier communications (Section 4.5), there is considerable doubt that most of the signals belong in this category. Additional measurements employing directional loopsticks will be required to establish the sources of each of the CW signals and of the broadband signal.

12/21/78, 1356, Artesia Freeway (north end)
HP 140, Whip, F 100 kHz, W 50 kHz, IF 3 kHz, ST 500 ms, RF 0 dB, IF -20 dbm

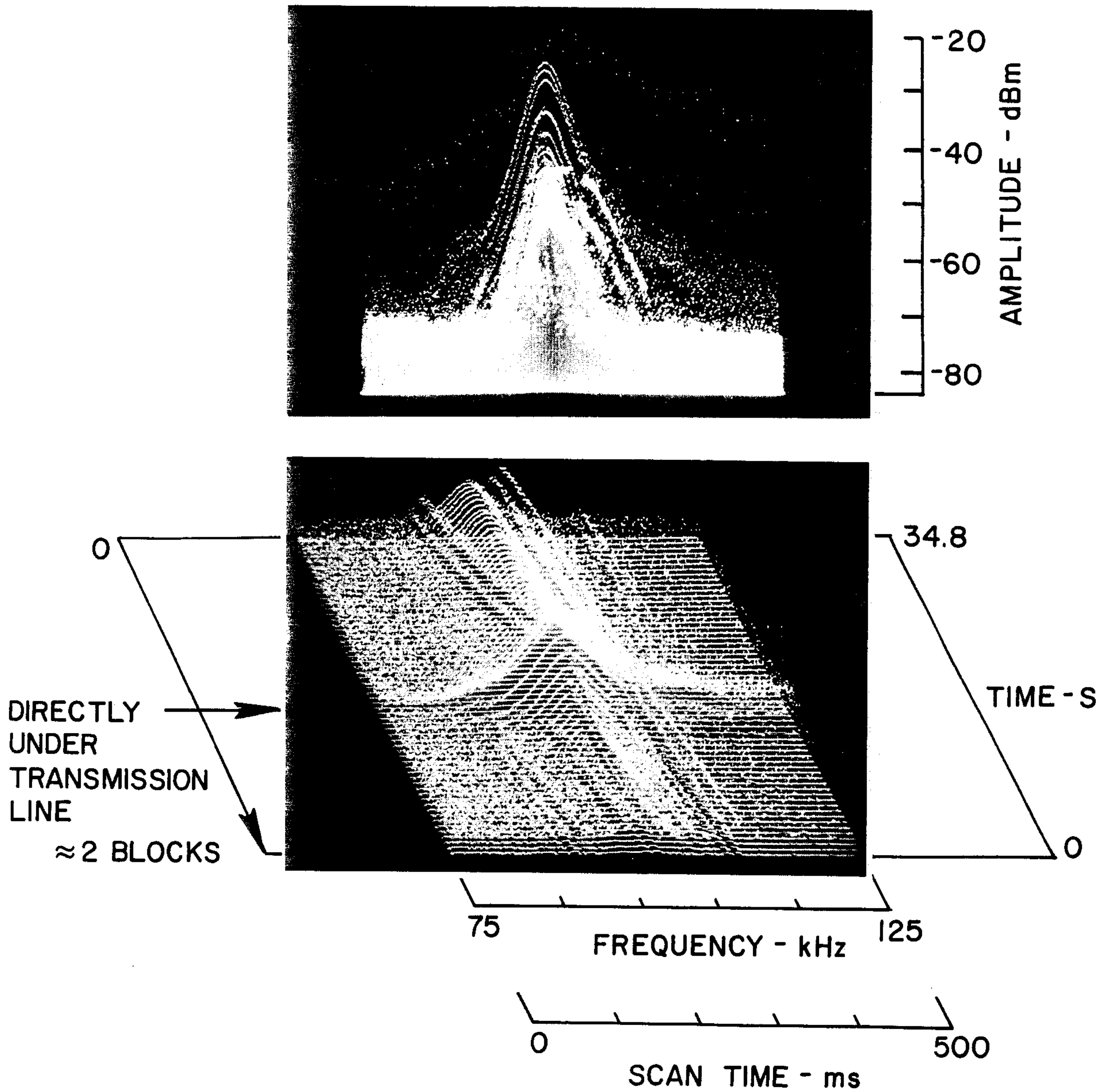


FIGURE 3-26. 12/21/78, 1356